ETI

4 5 5 Error 19 39 49 50 MOD 53 59 62 63 66 68 69 72

ELECTRONICS TODAY INTERNATIONAL

THE EYE THAT NEVER SLEEPS

Iris scanning - the new watchword in personal security

SINGLE PUSHBUTTON PIC SECURITY SWITCH

Compact, keyboardless coded lockout for equipment

DIY PCs - THE MAJOR UPGRADE

Reaching the parts to revive your PC

EASY PARKER

Precision LED parking aid

PLUS

- FAST FIVER TOUCH SWITCH
- CENTRONICS MINI-LAB DATALOGGER UPDATE
- 100W HIGH QUALITY MOSFET AMPLIFIER

9 770142 722160 08

FOR ENTHUSIASTS BY ENTHUSIASTS NEXUS

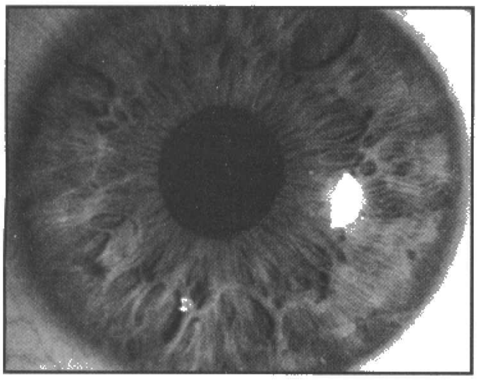
Vol. 27 Issue: 8 17th July 1998 - 14th August 1998
£2.75 U.S.A. $4.95

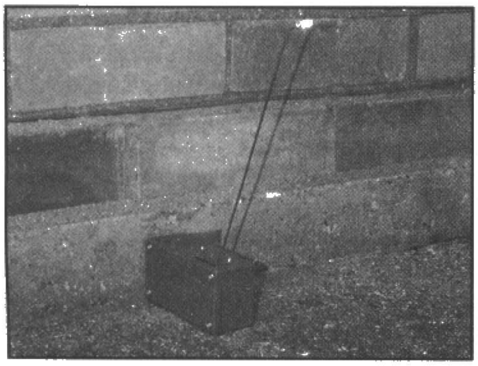
Contents

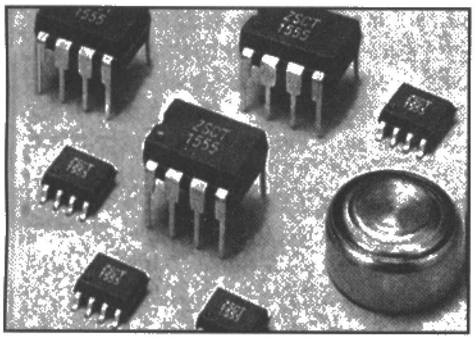
Volume 27 No.8

Features & Projects

Next Issue 14th August 1998







Regulars

ETI News...

Maplin CD Catalogue Updates

Anybody who wants an update on the Maplin CD Catalogue, or help with using it, can contact Maplin (address below).

Maplin reports that the installer does not always install the special Maplin font used in the catalogue. This may render some of the text unreadable. In Windows use your Start/Settings/Control Panel/Fonts to list the fonts on your system. If the Maplin font is listed, double click to display it and then restart the PC. It should now be available. If the font is not there and does not appear on re-install, contact Maplin for a copy of it.

Maplin also reports that some prices under Add To Order display bulk prices regardless of the number ordered. They are working on correcting this glitch, but say that the correct price will be charged when your order is entered.

Contact Maplin Electronics Plc., Maplin House, 274-288 London Road, Hadleigh, Benfleet, Essex SS7 2DE Tel (Customer Services) 01702 554002 web www.maplin.co.uk (You have to work around the site until you locate the Catalogues page - the FAQ are below the CD-rom graphic). Email techsales@maplin.co.uk

Software help for those working with the European Low Voltage Directive

The Low Voltage Directive is a piece of European law which has been slightly less widely discussed than the EMC regulations. It includes domestic mains supply voltages, and is called "Low Voltage" to distinguish it from National Grid voltage ranges. The intention of the directive is to provide a high standard of electrical safety in all appliances sold in Europe.

In order for any product to be sold, someone must sign a document stating that the product complies with the relevant directives. It is necessary for all products sold to be electrically safe, which may mean that it is necessary to test each item individually.

Whoever signs to say that the product complies is responsible not only for a "type approval" exercise on the design, but is also responsible for all production meeting the standard. The responsible person faces the penalties for non-compliance personally, and cannot pass the buck to production.

A debate on the merits of sample of 100 percent testing is emerging as manufacturers become aware that the range of the Low Voltage Directive goes beyond design and development. 100-percent testing may seem like overkill, but any practical failings of sample testing are further exposed when applied to electrical safety testing.

Insurance companies have shown an interest in compliance with the directive, and trading standards authorities have for some time had test facilities available in house. Therefore, compliance with the Low Voltage Directive is liable to be monitored closely. Authorities are showing a particular interest in the basic peripheral components of electrical appliances such as leads and power supplies.

Another area of concern is the number of no-European products offered for sale by importers who CE mark the products relying solely on the advice of their suppliers. While not wishing to adopt a "fortress Europe" mentality, importers also have a liability under the terms of the LVD and some large high-street names have a particular responsibility as major importers of popular lines.

EMC clubs, originally set up to help and advise on the Electro-magnetic Compatibility Directive, are increasingly turning their attention to issues such as the Low Voltage Directive and Machinery Directive.

Researchers have found that attempting to comply with the directive simply by reading it and following the procedures can easily lead to details being overlooked, or incorrect identification of the applicable sections of the document. It appears that the major barriers to proper implementation of the directive are a lack of knowledge on testing requirements, and lack of experience of the necessary technical documentation which must accompany a declaration of conformity.

Expert Consultant Ltd. have brought out a software package to help users to apply the directive properly, via a user friendly interrogation process. Test requirements, pass-fail criteria, and fault diagnosis are included. The software allows production of the essential documentation, such as the declaration of conformity and the technical construction file. With the emphasis of the directive on the provision of evidence and traceability of due diligence, correct documentation is vital, and a recent survey carried out by Expert Consultant Ltd suggested that 71 percent of organisations need to change their test recording procedures and technical documentation.

A free demonstration disc and brochure is available from Expert Consultant Ltd., Bracken Hill South West Industrial Estate, Peterlee, County Durham DR6 25W. Tel 017071 224329 or look at their website at www.expert-consultant.co.uk

ETI ELECTRONICS TODAY INTERNATIONAL News...

Ambyr Software Gives Stripboard New Colour

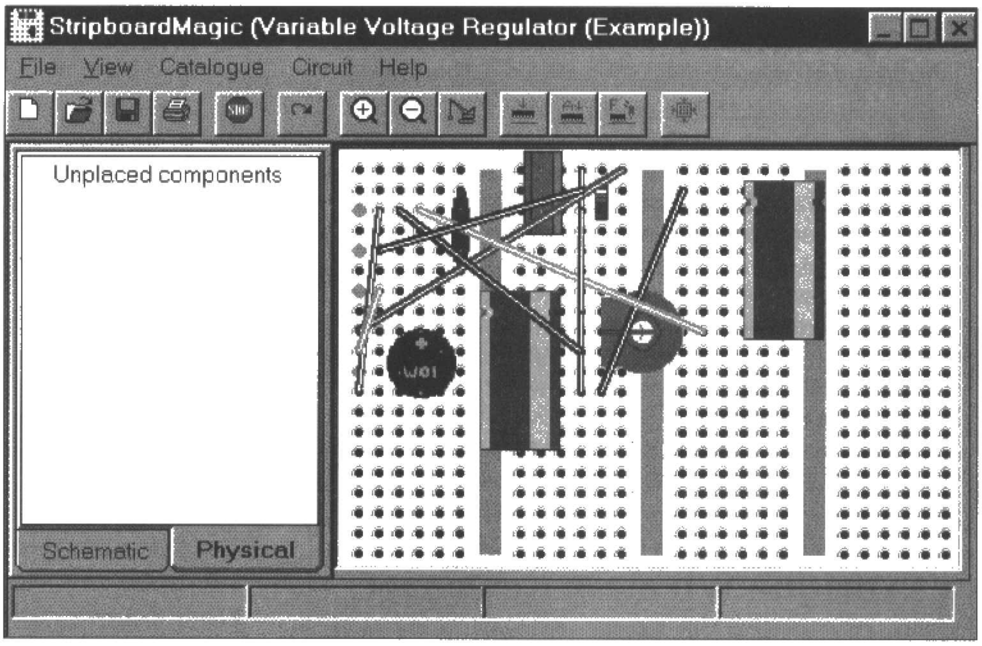
StripboardMagic is a new low-cost versatile circuit layout aid program designed to take the strain out of prototyping electronic circuits. You can enter the schematic into the software, and StripboardMagic will produce a breadboard or stripboard layout in moments, eliminating, the manufacturers, Ambyr hope, the tedious trial and error of physically laying out circuits.

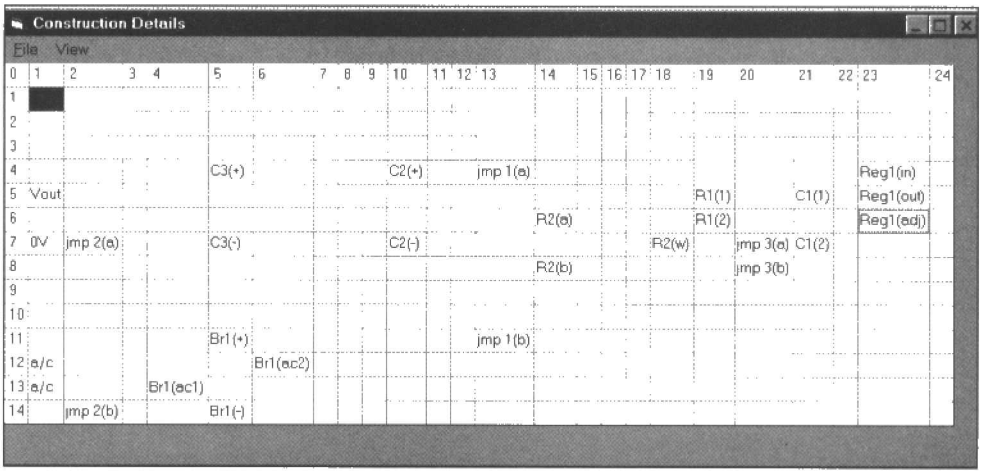
StripboardMagic also produces a table of component positions to make it easier to set out the circuit. In addition, StripboardMagic will automatically generate an order form of components for the circuit.

The program features an expandable component library; simple drag-n-drop circuit editing in schematic view; rubber-banding for connections and fully-automatic layout in physical circuit view.

The makers recommend the program for amateur electronics enthusiasts, educational establishments or commercial companies, and are sure that it will both assist and delight.

Stripboard Magic is available for £39.95 from Maplin Electronics Tel 01702 554155, and can be viewed on Ambyr's website at www.ambyr.com





MODMODMODMODMODMOD

Issue 5 1998 (24 April 1998)

Magnetic Swipecard Reader: In the software, the statements:

while I<200 do andif I<300 then print else (etc.)

Should read:

while i<200do and if i<300 then print else (etc.)

This appears to have been introduced by a helpful wordprocessor autocorrect that does not like to see an isolated lower case i.

Audible Logic Probe (Fast Fiver No. 9): Figure 1, the circuit diagram, should show R3 (10k) between pin 4 of ICI and the base of Q1. The stripboard layout and parts list are correct

In the 100W MOSFET Amplifier (Issue 7, 1998) in figure 4, the circuit diagram, R11 2k2 should be shown between the base and emitter of Q2 (just below RV1 on the diagram). In figure 5, the component layout, the label +V at bottom left should read 0V. However, the same 0V track is correctly labelled at top left. ZD3 (top right) is shown in the wrong orientation: the cathode should go to +V. The amplified diode on page 48 is Q7. Please write to Jenny Etheridge at Nexus House if you would like corrected copies of these two diagrams.

In the Parts List, C14 should be 100pf (BX28F) and the 47p BX26D is C15. The 100u capacitors C9,C10,C11 and C12 should be 25V, Maplin no. AT48C. These are shown correctly in figures 4 and 5.

To obtain a copy of the current MODSMODS sheet, please write to Jenny Etheridge at the address on page 74. An SAE is always appreciated.

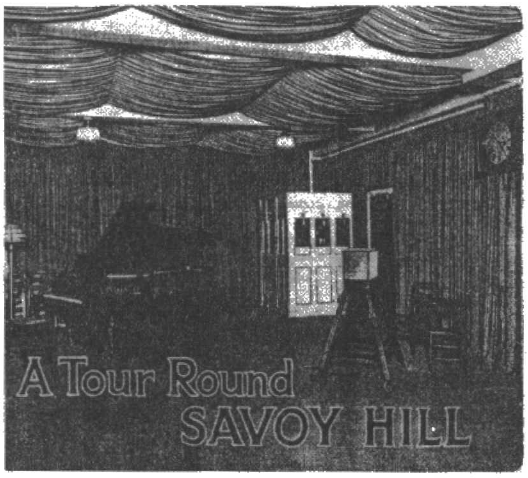
News...

Antique Wireless Newsheet 166

Out now, *The Antique Wireless Newsletter*, now from "Savoy Hill Publication". As ever, a source of news and views and, this time, of galena radio crystal, boxed for £2 or unboxed for £1. "Radio Tested - can be broken into multipes" says AWN. Dr. Tudor hopes to get some other crystal types traditionally used in crystal sets in the near future.

Contact Savoy Hill Publications, 50 Meddon St., Bideford, North Devon EX39 2EQ Tel/Fax 01237 424280 Email tudor.gwilliam-rees@virgin.net Web freespace.virgin.net/tudor.gwilliam-rees £5 for 12 issues UK, £7 for 12 issues overseas airmail.

The
Antique Wireless Newsheet
166



Lost in Space

"Think of that little room under the stairs where you keep the vacuum."

- NASA engineer asked to describe the private accommodation available to married couples on the first manned flight to Mars. *(Mail on Sunday)*

"Typical! The minute a woman volunteers for space flight, someone starts on about the housework."

"These young folk don't know when they're well off. It were a broom cupboard in my young day."

"Outside."

ETI editorial staff asked to describe where you keep the vacuum in an interplanetary space craft.

New Undergraduate Teaching Pack from the Open University

The Open University has produced a new set of multi-media learning resources titled Inside Electronic Devices: Engineering of Information Technology. The resources "address the questions about gathering, transmitting, storing and displaying information electronically", including the relationship between electronic properties and devices, and investigating many electronic phenomena such as dielectric behaviour, magnetism, semiconduction, thermal and optical properties.

The set comprises two self-study workbooks, two videos, and supplementary material, assuming a familiarity with the main concepts of materials, basic electrical ideas and principles, algebraic expression and mathematical models. They are also recommended by the OU to academics and lecturers teaching these subjects in their own departments.

For further information contact The Marketing Department, Open University Worldwide Ltd., Berrill Building, Walton Hall, Milton Keynes, MK7 6AA or call Anji Kellett Tel 01908 858791. Email ouenq@open.ac.uk

"Baby" Reborn in Manchester

To commemorate the happy arrival of the world's first stored-program electronic digital computer 50 years ago this June, the computer itself, known as "Baby", has been rebuilt and is on display at the Manchester Scientific and Industrial Museum. Roughly the size of two large free-standing wardrobes, Baby was the forerunner of today's data-storing computers, without which today's desktop computing that we know and love, CAD, Tomb Raider, etc. would be unthinkable.

The memory unit was built around a cathode ray tube that could "remember" 2048 bits. CRTs, which can store data for a limited time using the phosphor persistence, were one of a number of memory solutions tried with some success, but quickly outrun by magnetic ring memory cores in the early days of computing.

ETI ELECTRONICS TODAY INTERNATIONAL News...

Kenwood Power Supplies at Lower Prices from Feedback Instruments

Kenwood PAC and PAC-R regulated DC power supplied used in test engineering, universities and schools and serious hobbyists are available from Feedback Instruments at lower prices, starting from around £122 for the PAC20-3.

The range of six supplies includes instruments with 20V, 30V or 60V output at currents from 1 amp to 3 amps. ALl have low rippled and low noise characteristics, simultaneous setting and display of voltage and current with a 3-digit LED display for each, and floating output terminals.

The four PAC-R models have remote control terminals on the rear panel which can be used for the control of output voltage and current by external resistance or voltage. There PAC-R models also offer serious/parallel operation, by which the output current can be increased by series operation and the output voltage by parallel operation, and a remote sensing terminal facility by which the PAC-R can monitor and stabilise the voltage at the load.

For more information contact the Marketing Department, Feedback Instruments Ltd., park Road, Crowborough, East Sussex, TN6 2QR, UK. Tel 01892 653322 Fax 01982 663719 Email feedback@fdbk.demon.co.uk Web www.fbk.com

100 MS/s PC-based oscilloscope from Pico

Pico Technology's ADC 200-100 PC-based oscilloscope combines a 100 megsamples/s dual-channel scope with a 50-MHz spectrum analyser. As a "virtual" instrument, it offers functionality comparable with a benchtop scope, along with the advantages of data storage, such as the ability to annotate, save and print waveforms, as well as context-sensitive Help and the ability to copy and save waveforms into a wordprocessor.

The Picoscope software provides facilities such as simultaneous views of the scope, spectrum and meters, and displays of both live and reference signals in the same window. Two trigger modes can capture intermittent and one-off events: the Display Overwrite mode highlights differences from the normal waveform, and the Write to Disk mode saves the waveform to disk with a time and date stamp each time a trigger event occurs.

A spectrum analyser option is useful for applications like tracking down noise from mains hum, switching power supplies and microprocessor clocks, which are difficult on a scope display. The 50MHz range of the ADC 200-100 (compared to the 25MHz range of the ADC 200-50) also covers the range required for EMC conducted noise tests.

For users who wish to write their own software, drivers are included for DOS and Windows (16- and 32-bit). Also included is a macro to allow data to be collected directly into a Microsoft Excel spreadsheet.

In applications such as education and training where groups of people have to watch the screen at the same time, a PC colour screen provides a much larger and more visible display than a benchtop scope display.

For more information contact Pico Technology, Broadway House, 149-151 St. Neots Road, Hardwick, Cambridge CB3 7QJ. Tel 01954 211716 fax 01954 211880.

OVERSEAS READERS

To call UK telephone numbers, replace the initial 0 with your local overseas access code plus the digits 44.

ETI News...

FPGA advances from Actel and Lucent

Silicon Sculptor is a new Actel device field programmable gate array programmer (FPGA) for use with PCs. The programmer's extremely compact size makes it easier for designers to work from desktop PCs rather than in a lab. The programmer has a single adapter module that can be used to program all Actel devices of the same package type regardless of the number of pins, and up to four programmers can program up to four devices from one PC via connection with an expansion cable. The programmer gets the fuse file (including instructions on programming an FPGA) which it uses to program the device from Actel's Designer Series software. Optional Silicon Explorer diagnostic debugging software provides functional and timing verification of every internal signal after programming.

Actel has developed Silicon Sculptor jointly with BP Microsystems of Houston, Texas. The modules are designed to be fully upwards compatible with all BP antifuse FPGA programmers (for permanent heavy-duty programming of production devices), allowing design engineers to move from prototype programming to high volume production programming.

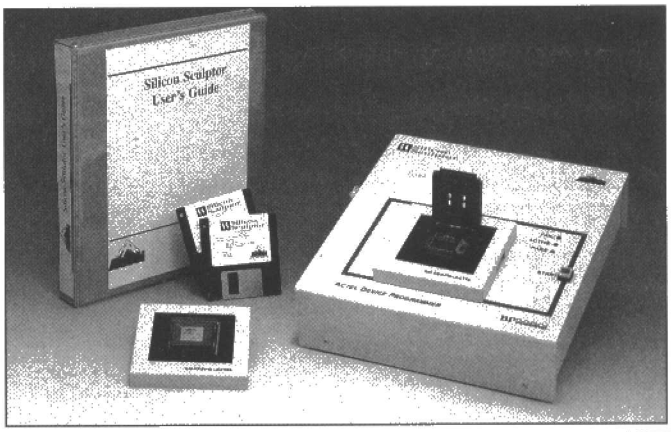
For more information, contact Actel Information Centre, Direct Mail Systems, 6 Woodbury Lane, Clifton, Bristol, BS8 2SD, UK. Web: www.actel.com

The Microelectronics Group of Lucent Technologies has released its Orca (TM) Series 3 family of FPGAs designed for greater speed and higher density. in 3-volt and 5-volt versions, the new devices offer gate counts of 55,000 and 80,000, with 125,000-gate devices scheduled for later this year. The 5V devices are made in a 0.35-micron 4-level metal cmos process, while the 3.3V devices use a 0.25-micron, 5-level metal process.

A development from the Orca 2C/T line, the Series 3 family more than doubles the logic available in each cell, offers a speed increase of 20 to 40 percent, has enhanced ability to route to available gates before connections are no longer available, and provides logic functionality that "blurs the distinction between FPGAs and complex programmable logic devices (CPDLs)". New system-level features simplify programming, reduce logic requirements and increase system speed. The new family is supported by a new version of the Orca Foundry FPGA development software, which includes special functionality for submicron devices such as these.

Series 3 system level features among others include a programmable Clock Manager that adjusts the clock phase and clock duty cycle for system clock rates up to 120MHz. Two clock managers per device can work either in phase locked look (PLL) mode or delay locked look (DLL) mode to give automatic clock multiplications 1/8x to 64x. Combining the manager with FPGA logic allows designers to create complex functions such as frequency counters and frequency synthesisers.

For more information contact Keith Gilliard, Marketpoint Europe Ltd., Osprey House, Berkeley Business Park, Finchampstead, Berks GR11 4YJ, or the Lucent Technologies Dataline Tel 0118 932 4299 Fax 0118 932 8148. Web: www.lucent.com

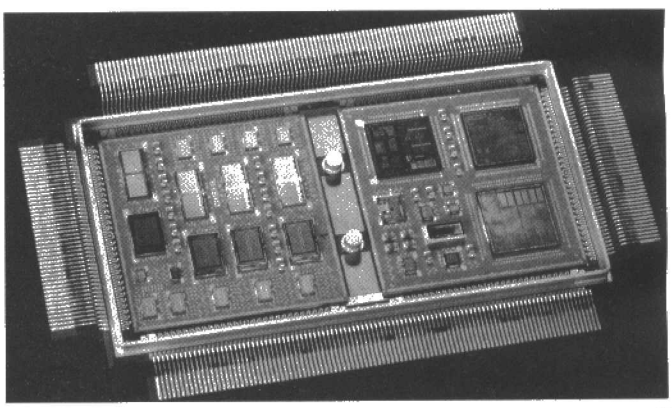


Flexible Avionics Computer Module can Compensate for Obsolete Circuits

UK distributors GD Technik have imported Diehl Microelectronics' Modular X multi-chip computer module. The Modular X will form the kernel of radar and weapons systems in future aircraft, and has the ability to compensate for circuits that may become obsolete within the system. An obsolete processor or memory can be replaced by pin- and functionally compatible modules with the use of the appropriate drivers and operating system. This flexible approach means that no extra redesign costs or qualification costs are added to the system. This is an advantage as redesign and re-qualification within systems can introduce errors and compatibility problems as well as address them.

Modular X embeds high-end processor cores with support peripherals and memories inside a radiation-hardened military-specification miniature metal can. It is constructed from a combination of substrates that are thermally matched and tested before and after assembly. In also offers an operating temperature range of up to 250 degrees C, and enhanced EMI/RFI protection. Each multi-chip module comprises the microprocessor, a peripheral processor, an a array of uarts, timers, parallel I/O, 1553 RT/BC and a watchdog. High density SRAM, eeprom and Flash memories can be added, and there is an option t implement an FPGA.

For more information contact GK Technik, Tel 0118 9342247 Fax 0118 9342896 Web www.gd-technik.com



The Eye That Never Sleeps

In the near future we may be exchanging a wallet full of credit cards for hand-and-eye identification. The latest development in automatic biometric identification by iris scanning has recently begun a pilot scheme in the UK.

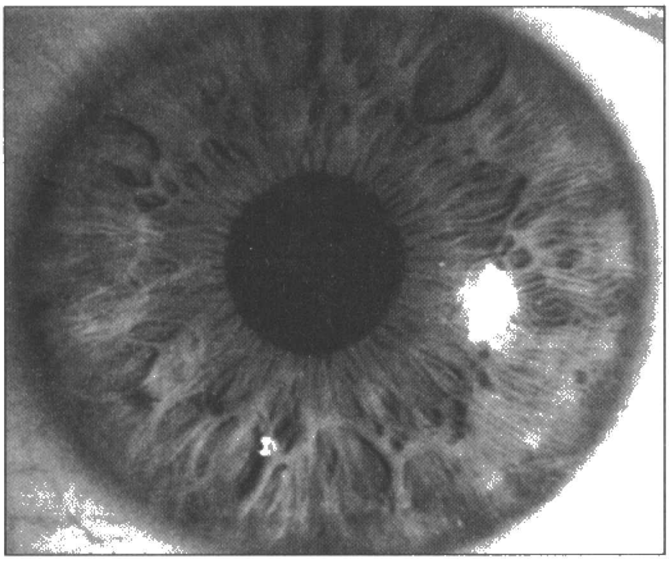


Figure 1: the structure of the human iris is both immensely complex and mobile, yet undergoes few substantial changes in the course of a lifetime. This renders it very useful for identification purposes

"Computer theft" these days is just as likely to mean somebody hacking into confidential computer files and removing the information as it is to mean a vanload of burglars with PCs in the back (although the latter is by no means out of fashion). Finding new ways to avoid popular crimes such as credit card frauds and automatic teller machine (ATM) robberies is an expanding industry.

The science of biometrics may prove to be the ace in the hand. Controlling unauthorised access to buildings and computers by techniques including fingerprint reading, voice and facial recognition and eye scanning have been around for a while, but mainly in pilot schemes and almost invisible to the general public. That is changing fast in the USA, and will soon become more apparent in the UK. In April, the Nationwide Building Society's Swindon branch began a six-month trial of an iris-reading system built into its cash machines.

The iris of the eye might be one of the most sensitive and vulnerable parts of the human body, but in biometric terms it is the opposite. The network of connective tissue and other features in the iris of every human eye - including those of identical twins - forms a pattern so different from every other eye that it is distinctive even from its own opposite number (**figure 1**). The reason for this high degree of individuality is that the precise formation of the iris (other than the colour) is not determined purely by inheritance but is partly formed by the emergence and growth of the visual aperture, the pupil, of which it is the muscular boundary. This can be roughly expressed by saying that the formation of the iris is phenotypic (shaped by individual growth) rather than genotypic (resulting directly by the genes). There are around 266 different elements to the iris pattern, providing sufficient redundancy that even if some elements change due to damage or illness, there are still plenty remaining for accurate identification. Around 70 percent of the available features still provides a good reading. The element that humans notice - the colour - is not used at all. Processing uses a greyscale of the structural elements that are far more distinctive on a micro scale.

The iris is installed in its own casing - the cornea of the eye, and the aqueous humour behind it - which protects it (unlike fingerprints) from scratches and dirt. Being visible from outside (unlike the retina of the eye, which is also used in some security scanning systems), it can be imaged usefully at up to three feet away if the owner looks at the camera.

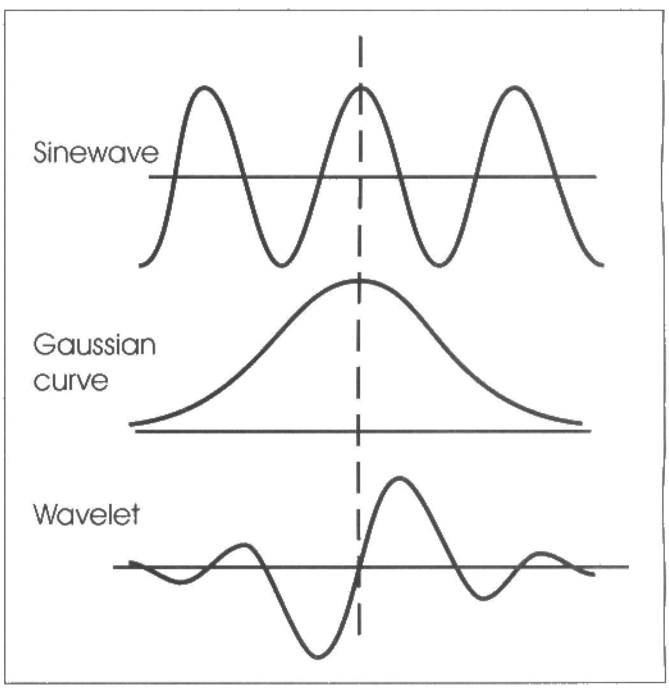


Figure 2: the general form of a wavelet

Figure 3: face recognition correlation peaks

So complex and stable is this structure that it is not distorted significantly by the expansion and contraction of the pupil of the eye in response to light, or significantly changed by ageing.

The iris is readable through glasses and contact lenses, even coloured ones.

The retinas at the back of the eye can also be scanned, but use shows that people experience these as being intrusive, and are not happy about having bright lights routinely shone into their eyes. The characteristics of the retina also change significantly over a person's lifetime.

Just look ...

The advantage of iris scanning is that the owner simply looks briefly at a camera to enable the image of the eye to be passed back to the data processing system which should already have that image stored alongside, for example, the owner's banking details. There is no contact between scanner and the scannee, so there is no wear and tear, and minimum processing on the part of the scanee.

Capturing the image for the data system, or "enrolling", is almost as simple. The subject has one eye photographed, usually at about 10 or 12 inches distance, by a small camera (not unlike the monitor-top "webcams" used by Internet users who want to send snapshots or even video phone images) at their own branch. The camera feeds a video signal directly to the computer ram, and the image is processing and stored as a barcode-type data file, named the IrisCode (tm) by the owners of the technolgy, IriScan of New Jersey, USA. When the eye is "seen" again by an iris reader, normally a solid-state camera built into an ATM, for example, the image generates another IrisCode to be compared with the original. The iris reader can be networked to a server database which can hold as many IrisCode files as the system requires. The database can be searched in real-time regardless of the number of codes stored in it, provided the size of the database is matched to appropriate memory and processing design.

The whole process is a bit like acquiring a passport photo at a photo booth - but without that embarrassing self-portrait to stare back at you every time you use it.

Iris recognition

Identifying individuals by optically scanning the iris demands no special skill from the user, seems to have a high reliability and ultimate simplicity, but needs probably more scientific and technical sophistication than most other methods.

The first requirement is to locate an eye automatically. This is simple to say and difficult to do. John Daugman, of the Computer Laboratory, University of Cambridge, uses complex 2D Gabor wavelets both for this, and to represent structures in the iris once that has been located. The wavelets are a powerful analysis tool, necessary to make iris recognition practical.

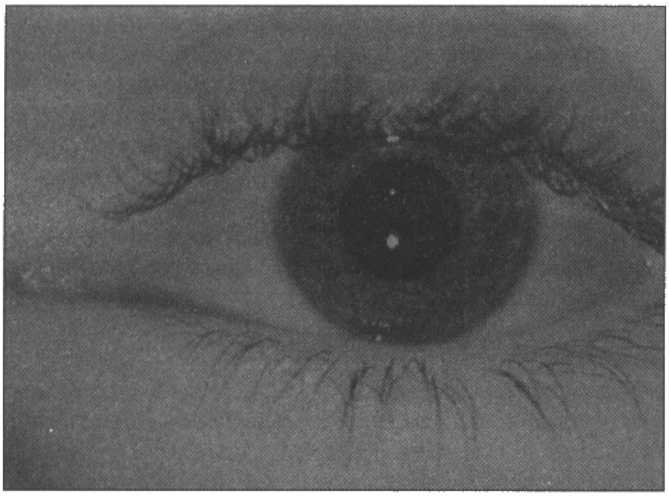


Figure 4a: a raw iris pattern imaged at a distance of about 50cm

What about wavelets?

The idea that a continuous waveform can be represented as a series of sine and cosine waves, which can be determined by performing a Fourier transform, is probably familiar to most readers. Not only can an audio or electrical waveform be represented thus, but so can an image. For example, a picture of black and white lines would be an optical square wave, which could be represented as:

$\sin(x) + 1/3 \sin(3x) + 1/5 \sin(5x) +$ (and so on).

This is an infinite series of which we have printed the first three terms, and it represents an infinitely long square wave. However, a fairly accurate representation is possible with only a few terms.

In contrast, to represent a short series of light and dark lines, or even a single one, needs a very large number of terms. Try to imagine a set of sinewaves that adds up to zero from minus infinity to plus infinity, except for one positive pulse, and the problem becomes apparent.

Converting images to frequency components is actually used in some applications, despite the apparently insuperable problems. JPEG image compression uses a discrete cosine transform to determine the frequency components present in an area of picture. Then, as a step in compressing the image, some of the high frequency components are removed. One drawback of this technique is that, particularly at high levels of compression, the squares over which this technique has been applied become visible. It is very useful, despite this.

For feature recognition, much previous work has concentrated on finding edges and corners. John Daugman has devised a technique analogous to frequency domain analysis, but using wavelets instead of sinewaves. Many different wavelet functions are used in different applications - the wavelets used here are two-dimensional Gabor wavelets.

(Denis Gabor (1900-1979), who invented the one-dimensional Gabor wavelet, was a Hungarian who worked for much of his career at Imperial College, London. He works in the field of Fourier optics and received the Nobel prize for the invention of holography in 1971.)

In general, a wavelet is a symmetrical waveform such as you might get if you took a sinewave and multiplied it by a Gaussian distribution curve. It starts and dies away, producing something which is localised in space, as shown in **figure 2**.

John Daugman has devised a two-dimensional version of the wavelet which is a good match to the sort of shapes forming the human face. Correlating this wavelet with an image of the face effectively demodulates it (**figure 3**), locating such features as the eyes and mouth.

Returning to the problem of locating the eyes, so long as the camera can see the face at all, it can automatically aim and zoom to gain an image of suitable resolution. When the eyes have been located, it is next necessary to locate the iris.

There are a number of practical problems to overcome in solving this: the size of the pupil can vary dramatically. Normally, the iris will be partly obscured top and bottom by the eyelids, and the extent of the obscuration is also a major variable. Even if these can be coped with, a further difficulty arises in that the eyelashes themselves can obscure part of the image. For the system to work, it must be able to ignore obscured areas and scale itself to do all measurements relative to the instantaneous size of the iris. In addition, it must have a robust correlation system, which can give a result to a high degree of confidence despite a number of bit errors.

Unpredictable bit errors can be caused by reflections, obscuration by eyelashes, noise on individual pixels and any other tolerances in the system.

The system uses near infrared light to illuminate the eye, and the reflectance of various parts of the eye can be very different in the infrared region than they are using visible light. The pupil might be the lightest part of the image, particularly in the case of older subjects who may be suffering the onset of cataracts. The software must cope with this by looking for edges, rather than for specific transitions from light to dark or dark to light.

The use of infra red light also helps with the problem of identifying fakes (also see below). A fake iris which looks indistinguishable to the human eye in normal illumination, may look very different when illuminated in infra red, due to the different reflectivity of the materials.

The size variability of the iris is coped with by using a doubly dimensionless co-ordinate system, which maintains reference to the same details of iris tissue regardless both of the size of the pupil and the overall size of the image. This means that, as long as the zoom factor is sufficient to give the required level of detail, and not so much that part of the iris is out of the picture, then its size in the image is unimportant. An image of the taken at about the middle of the useful range of distances is shown in **figure 4a**, and the location of the iris within the eye area, with its the zones of analysis, is shown in **figure 4b**.

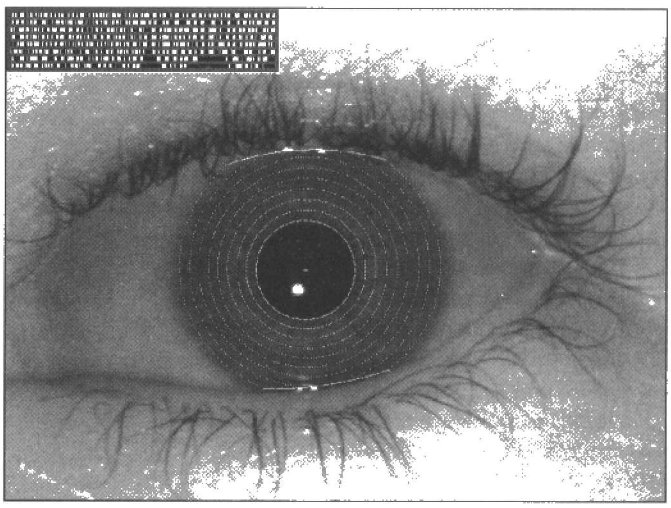


Figure 4b: locating the iris and eyelids: the iris isolated and demarcated into zones of analysis, and an illustration of the computed IrisCode

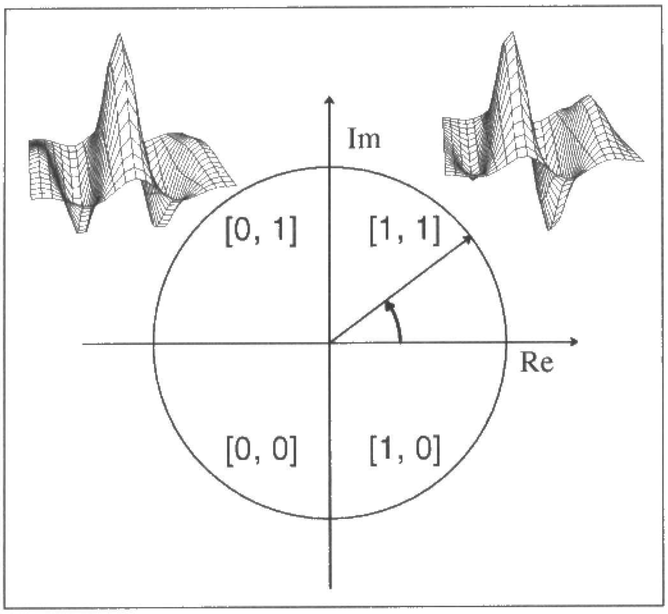


Figure 5: a phase quadrant iris demodulation code

Iris code

Now that the iris has been located, it is necessary to generate a code from this image information in such a way that the code is reproducable with repeated scans of the same eye (even with a subject in different lighting levels, states of health, etc.). It is also important that this code should be different from the code generated by any other eye.

What John Daugman does is to use a pair of two-dimensional Gabor wavelets in which the "wavelet frequency" in one is 90 degrees phase shifted compared with the other, relative to the waiting function which forms the wavelet.

To allow a computer based comparison method, the comparison result must be coded in a binary fashion. The John Daugman approach is to correlate a given area with the "real" and "imaginary" wavelets, and produce a 0 or a 1 for each comparison. Thus, each textural detail analysed is coded into 2 bits, defining the complex quadrant in which the detail falls. John Daugman has named this code a "plixit" - a word to refer to the phase code for a local iris striation.

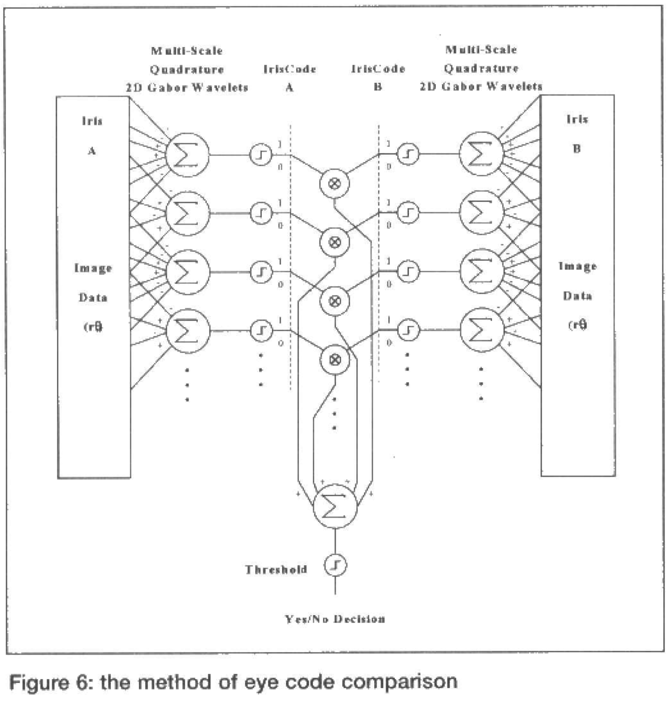


Figure 6: the method of eye code comparison

This is illustrated in **figure 5**. Those familiar with modem or some types of wireless telephony coding techniques may notice the similarity in concept between this and the method of coding more than one bit with a single carrier vector. The simplest of these, coding two bits at a time, is effectively phase modulation, and gives rise to phasor diagrams just like this one.

This correlation operation is repeated all across the iris, at many different scales of analysis, to produce a 256 byte iris code.

Decision time

Clearly, as noted earlier, not all bits of the iris code will match from one scan to the next. It is necessary to use a comparison method able to distinguish between acceptance, when most of the bits match, and rejection, when most of them do not match. This decision process is illustrated in **figure 6**.

The bits in different iris codes can be compared at about 100,000 iris codes per second on a typical desktop PC, and at hundreds of millions per second using dedicated hardware (because only XOR operations are needed).

Using integer XOR logic, in a single clock cycle a long vector of each of two iris codes can be XORed to generate a new integer, each of whose bits represents mismatch between the vectors being compared. The total number of 1s represents the total number of mismatches between the two codes. The length of the vector in n-dimensional space represents the distance between the two binary codes - this is referred to as the Hamming distance.

A question to be answered before iris codes can be used as a means of identification is "Is there sufficient independent variation in iris patterns over the population?". That there is, is confirmed by this plot, (**figure 7**), showing the probability of a given bit being set. This is the result of a survey of a large number of people, and if there were a systematic tendency for one part of the iris to be textured in a particular way, then the plot would not be so close to flat.

Figure 8 shows a graph of numbers of comparisons against Hamming distance, and it shows that, as one might expect, about half of the bits do not match. The important question is, what level of false matches could be expected? This depends on the Hamming distance chosen as the decision point. It turns out that, for a Hamming distance of 0.342, there is a 1 in 1.2 million chance of a false acceptance, and the same chance of a false rejection. This exceeds the accuracy of the other biometric identification methods covered here.

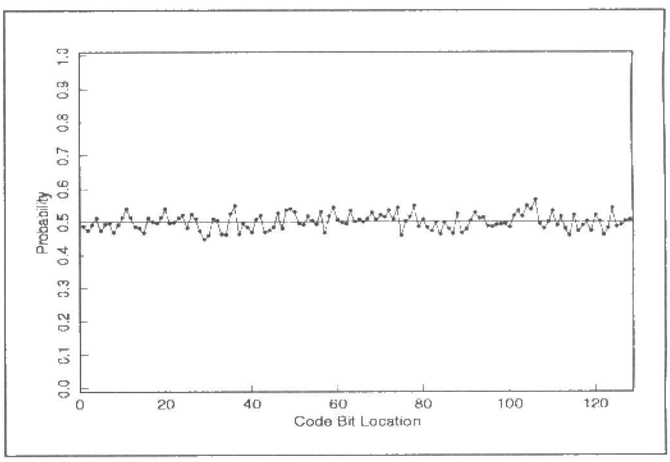


Figure 7: the probability of a bit set across iris codes

The system cannot be fooled by any simple means. For example, an iris pattern on a contact lens, no matter how accurately printed, gives a different reading than that from a real iris. **Figure 9** shows the 2D Fourier domain spectra from a real iris and from a fake iris printed on a contact lens.

Going Nationwide in the UK

In the Nationwide pilot, a camera enclosure about 12in by 6in with a transparent black front panel is mounted on the ATM. The customer has only to look at the camera area for a few seconds while a green LED blinks to let them know something is happening.

Behind the front panel are two cameras: one set to a fine field of vision and provided with a sophisticated tilt mirror to bring the focus close, and one set to a wider field. The latter camera "sees" a face and feeds basic facial feature data to the processor. This allows the processor to work out where the required eye is, and focus the second camera on the iris. This step could be carried out by a single self-focussing camera - and probably will be in the future - but it would take slightly longer.

The processor uses a circular grid to divide up the iris area in the same way that squared co-ordinates are used on maps. The system analyses the light and dark areas (**figure 10**) and generates a 256-byte "human bar code", the IrisCode (**figure 11**). This is checked against the one stored in the database. Typical recognition time averages about two seconds for the whole process. To give some idea of the speeds involved, the execution times for the critical steps using an embedded Intel 486DX66 processor at the time of publication, with optimised integer code, were:

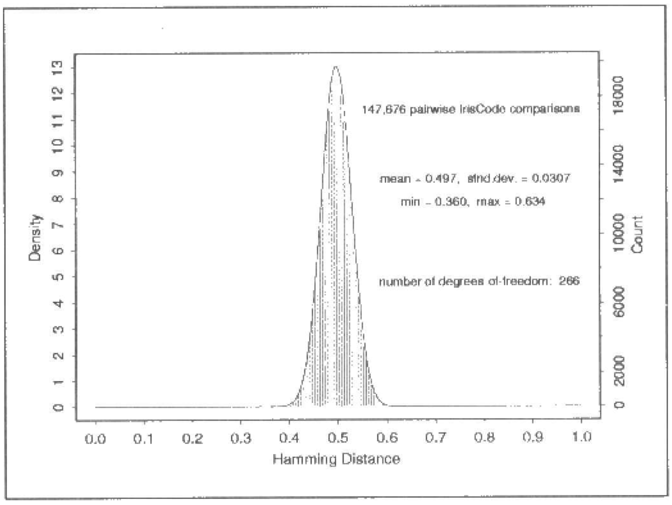


Figure 8: British Telecom iris code comparison results

Assessing image focus: 20 milliseconds
Localising eye and iris: 408 milliseconds
Fitting the pupillary boundary: 76 milliseconds
Detecting and fitting the eyelids: 93 milliseconds
Demodulation and IrisCode creation: 102 milliseconds
XOR comparison of two IrisCodes: 10 milliseconds

Faster embedded processors are now available. The stages from image acquisition to calculating the confidence level are shown in **figure 12** as they appeared on Dr. Daugman's 1994 patent.

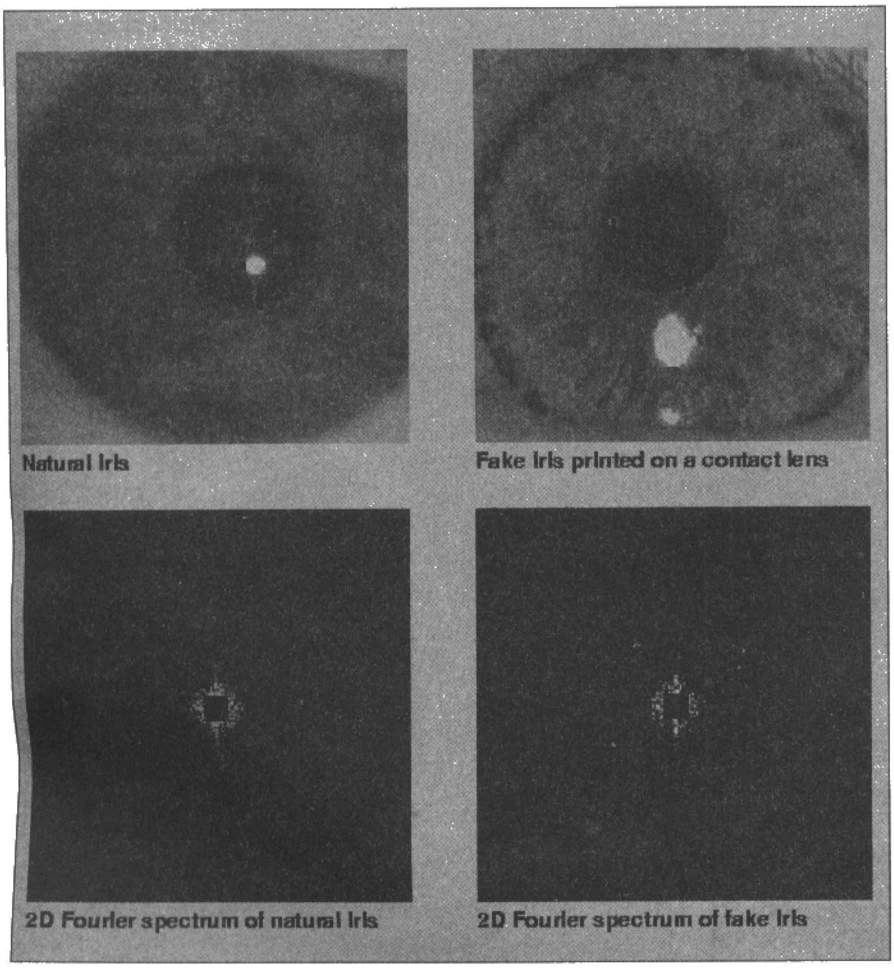


Figure 9: the different 2D Fourier domain spectra obtained from a real iris and from a fake iris printed on a contact lens

The near-infrared foreground lighting is provided by a low-level far-red bulb behind the black front panel. As well as picking out the iris features, this allows the eye to be read after dark, and also counteracts the backlighting effect of daylight behind the user's head.

When the customer inserts a bank card in the machine, the first menu asks if they wish to use a PIN or an iris scan. Use is entirely voluntary even when the customer is already enrolled for iris scanning. According to NCR (National Cash Registers) who provide the ATMs, take-up on the pilot scheme has been good, with few access failures and - more important - no erroneous matches. The only negative responses from customers offered the option of enrolling is from people who are afraid that - willy nilly - their eyes would be laser scanned. Ian Buxton of NCR believes this may be a throwback memory of low-level lasers used in retinal scanning - or just James Bond movies. But a camera can "see" the outer eye just as easily as a human can, without special lighting.

The main advantage of this system to security-minded owners is that the iris is a very reliable means of distinguishing one person from another. The complexity of the structure can be distinguished from a 2-D copy by small amounts of movement in the iris, which pass slightly different images with the same co-ordinates to the

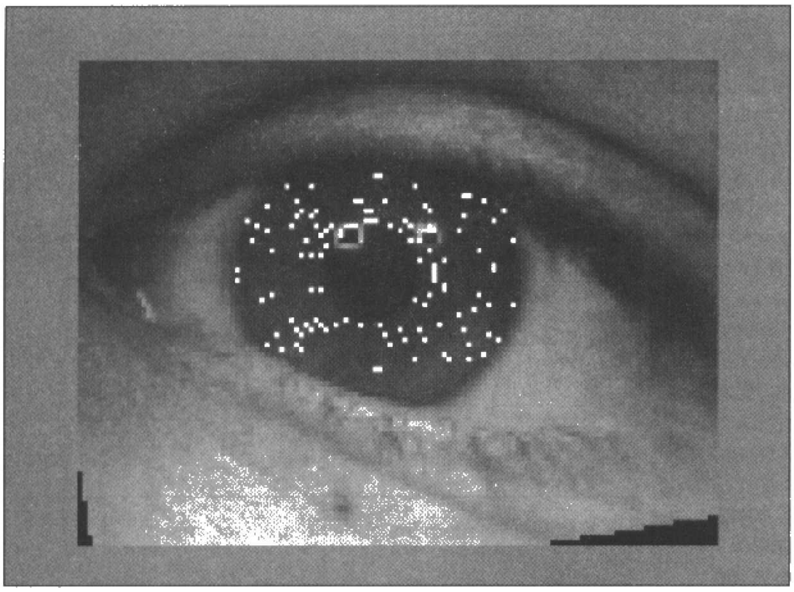


Figure 10: when the circular analysis grid is overlaid on the image of the eye, the system can read the light and dark areas of the iris and general the 256-byte IrisCode. There is sufficient data available that the areas obscured by the eyelashes and eyelids can be ignored

processor, confirming that there is a 3D, moving structure present. So, far from staring at the camera, it is better to relax and blink, allowing the pupil to flex the surrounding iris tissue.

The future

In a "full circle" effect, the camera system provides, Sensar Inc., who specialise in iris scanning applications, believe that they could incorporate the small IrisCodes onto a smart card, so that the eye-scan could be compared without rephotographing the eye. This would obviously be less secure, as cards can be stolen, but retains the advantage of complete individuality and no PIN to forget.

IriScan themselves are also developing a hand-held image-capturing device (**figure 13**) that could make iris recognition mobile, and working on PC-based operating systems so that iris recognition can be widely integrated with other equipment.

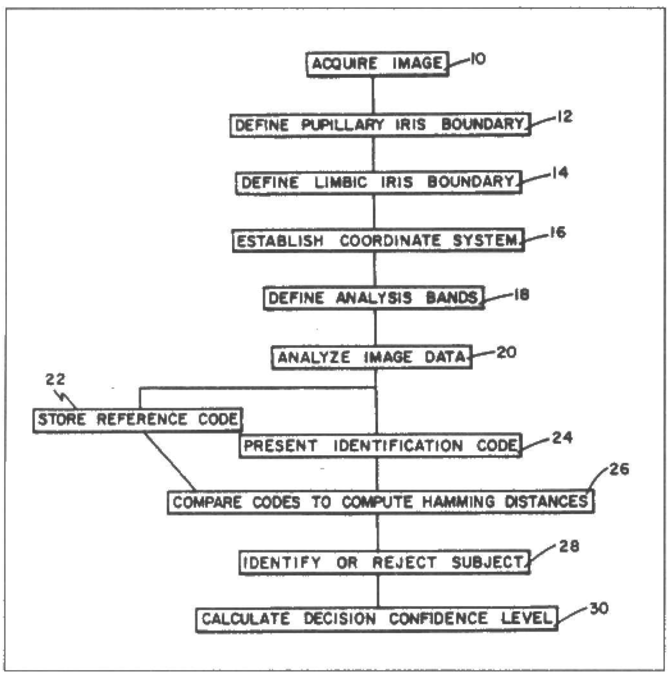


Figure 12: the stages from image acquisition to calculating the confidence level in the 1994 patent

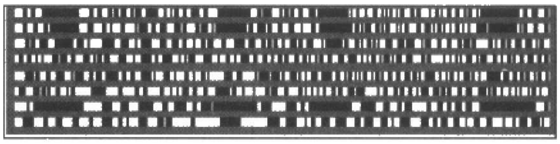


Figure 11: an illustration of the "human bar code" or IrisCode generated for digital storage and later comparison

A number of other companies are researching or making systems based on the Daugman iris recognition algorithms, including British Telecom who, with The Gatsby Foundation, gave grant support to the research.

Whether iris scanning will become widespread in the long run will inevitably depend on cost. However, the main advantage of this and other biometric technologies to the user is much simpler: the familiar tautologously-named PIN numbers will become redundant, and forgetting your number at just the wrong moment will become a thing of the past.

The iris recognition technology is owned and developed by the patentholders, IriScan Inc. of Mt. Laurel, New Jersey, conceptualised by Drs. Leonard Flom and Aran Safir and uses software and process technology invented by neural network and information theory expert Dr. John Daugman of the Computer Laboratory at the University of Cambridge in the UK (formerly of Harvard University in the USA and the Tokyo Institute of Technology).

Soon we may no longer have pockets and wallets bulging with credit cards, cash cards, loyalty cards and smart cards - we may be our own ID. Then, the most sensitive information in our lives may depend on only two or three sets of biometric readings, and the challenge will be to ensure that these biometric files cannot be stolen and used by the wrong people.

In the next issue, we will look at automatic fingerprint ID systems which are already widely used and will probably be appearing on familiar gadgets like mobile phones quite soon, and some other approaches to automatic biometric identification.

Pictures and diagrams courtesy of IriScan Inc., NCR and Dr. John Daugman. News and information about IriScan can be found on the web at www.iriscan.com

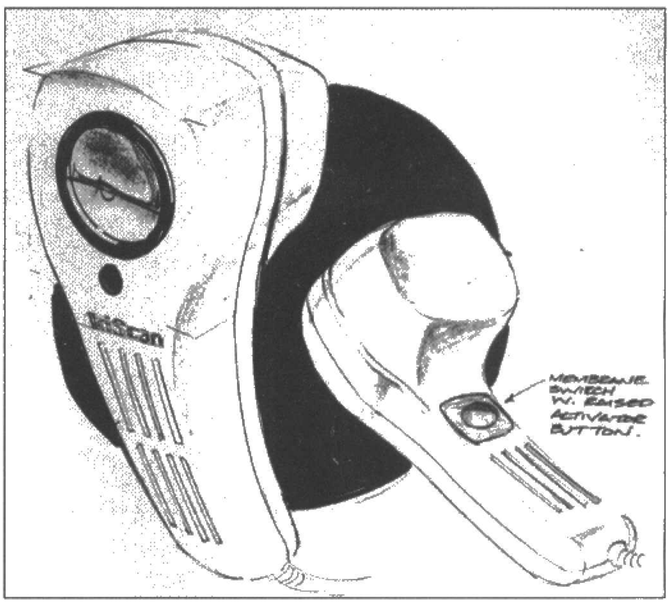
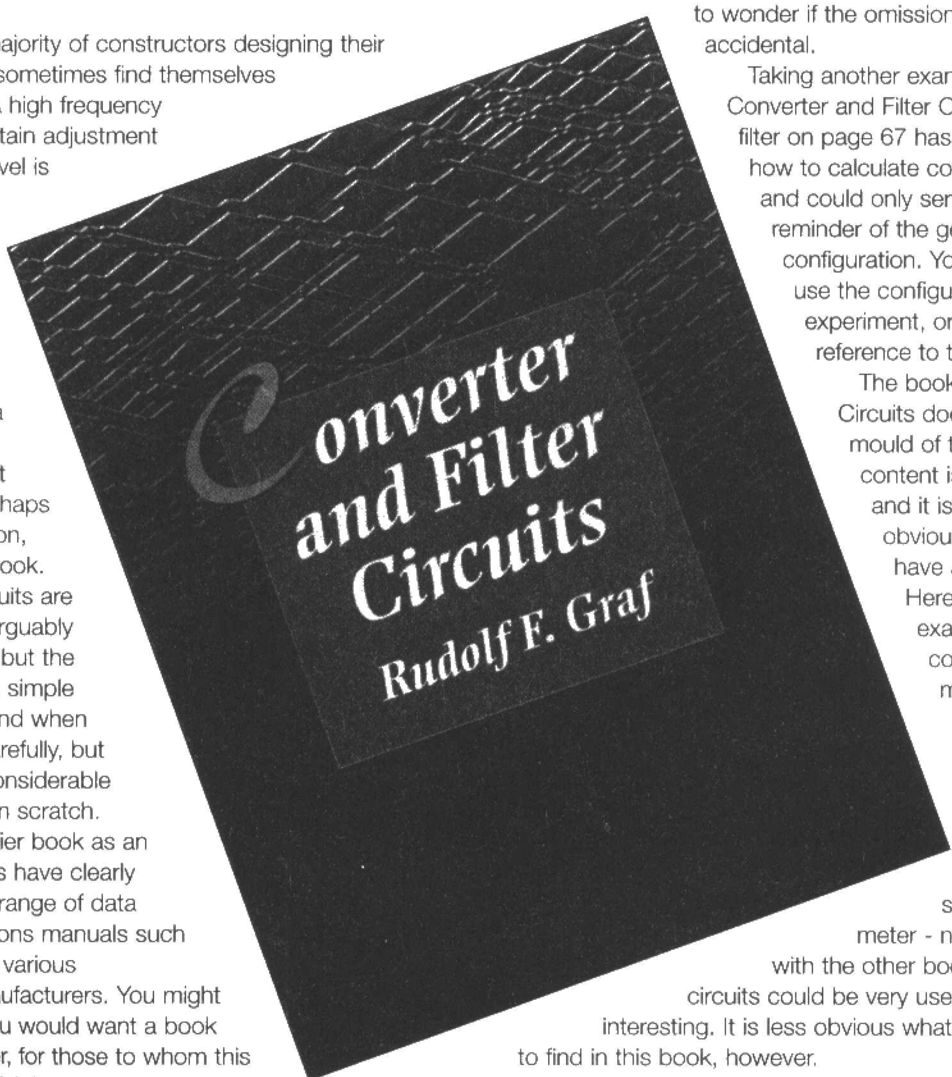


Figure 13: a predictive artist's impression from IrisScan of a handheld iris scanner under development

REVIEW

Oscillator Circuits
ISBN: 0 7506 9877 2
Amplifier Circuits
ISBN: 0 7506 9878 0
Detector Circuits
ISBN: 0 7506 9879 9
Converter and Filter Circuits
ISBN: 0 7506 9883 7

Four circuit reference titles by Rudolf F Graf
Newnes (Butterworth-Heinemann), Oxford



I imagine that the majority of constructors designing their own projects must sometimes find themselves stuck for a circuit. A high frequency oscillator, with a certain adjustment range and output level is needed, and the best approach to this is not immediately clear.

That is where this series of books comes in. There is a good chance that there will be a circuit suitable for use, perhaps with a little adaptation, somewhere in the book.

Some of the circuits are simple, and could arguably have been omitted, but the majority of them are simple enough to understand when you look at them carefully, but might have taken considerable time to think up from scratch.

Taking the amplifier book as an example, the circuits have clearly been drawn from a range of data books and applications manuals such as are produced by various semiconductor manufacturers. You might ask yourself why you would want a book like this. The answer, for those to whom this type of book is useful, is that when you want an amplifier circuit, it is much easier to decide what is needed by looking through a book showing examples of amplifiers from a range of sources, than it is to look through a series of manufacturers' data books searching for the amplifier circuits. The sources are credited at the end of the book, so if you find an application which is almost what you need, it is easy enough to look for further data from the relevant manufacturer. This is particularly useful now that semiconductor data is available on the internet (examples linked from the ETI site).

The style of circuit drawing is not consistent, presumably because the diagrams have been copied closely from data or applications manuals, rather than being re-drawn. This should cause no problems with comprehension.

Brief explanations

The downside of this kind of book is that the explanation of each circuit is necessarily brief. The value of the book is as a repository of a wide range of circuits, rather than as an explanatory text. In one or two cases, this can become a problem, as with the 1W 2.3GHz amplifier on page 129. The text copied as part of the diagram directs the reader to another figure, where the layout of the matching stubs is detailed. This figure is not present, so that in order to use the circuit either you must figure it out for yourself, or find the source document. At least it is referenced, as noted above, but the use of perhaps another half page would have provided the necessary information. One has to wonder if the omission was deliberate or accidental.

Taking another example, from Converter and Filter Circuits, the biquad filter on page 67 has no indication of how to calculate component values, and could only serve as a guide or reminder of the general configuration. You could perhaps use the configuration with some experiment, or search for another reference to this type of circuit.

The book on Detector Circuits does not quite fit the mould of the other three. Its content is more diverse, and it is not quite so obvious when it may have a suitable circuit. Here are some examples of its contents: an Air motion detector, Bug Detector, Fluid Level Controller, a range of types of peak detector, radiation monitor, stereo balance meter - need I go on? As with the other books, some of the circuits could be very useful, or just very interesting. It is less obvious what you may expect to find in this book, however.

This series of books is good for finding the type of circuit you need for the range of subjects which they cover. Few if any up-to-date semiconductors are used, but in my view this is relatively unimportant for a general reference work of this kind. The useful thing is to have a variety of circuit configurations to look at, if only to suggest avenues for further investigation. The circuits are there to provide ideas, rather than explanations, and they look useful in this role.

REVIEW

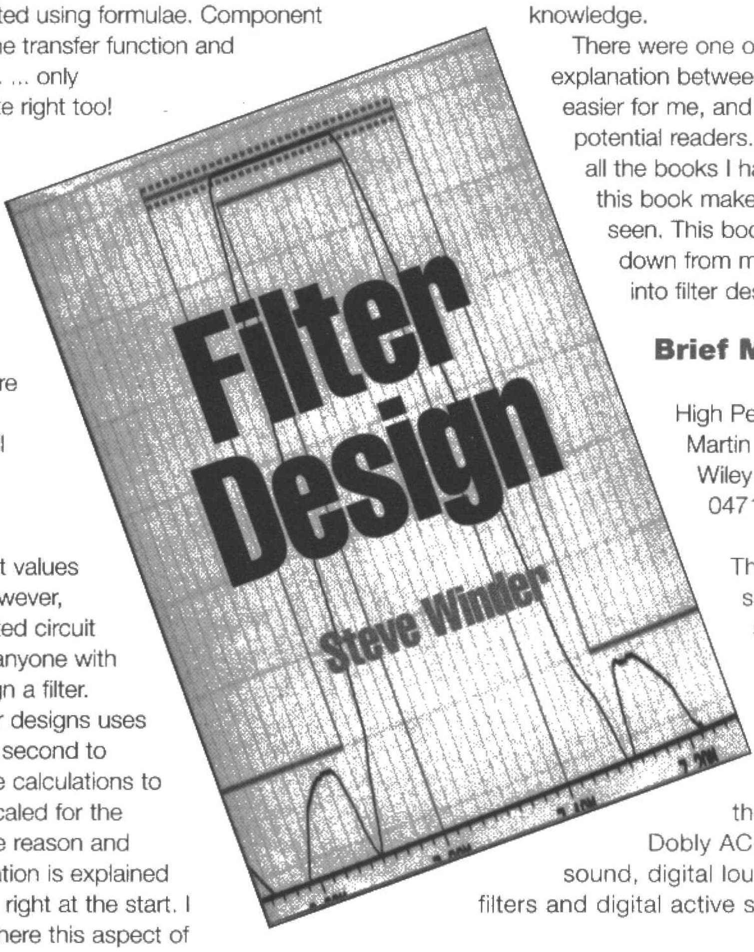
Filter Design
by Steve Winder
Newnes (Butterworth-Heinemann, Oxford
ISBN 0 7506 2814 6

Here is a book about a difficult subject, written by someone who has recognised this and done his best to make it clear.

Filter design is inevitably mathematical in nature, and in order to make the best use of this book you must have some understanding of complex numbers and Laplace transforms, among other things. If you do, then you have here the means to gain a practically based understanding of filters which many people will find easier than the heavily mathematics-led approach favoured by some authors.

For example, in the section on Bessel filters, near the beginning of the book, the author writes "Bessel passive filter networks cannot be calculated using formulae. Component values are found by using the transfer function and continued fractional division. ... only undertaken by heroes." Quite right too!

Unfortunately, the author does not detail exactly how the component values may be calculated from the transfer function, so that his suggestion that some readers may wish to try their hand at calculating lower order filter values, where relatively few stages of calculation are needed, is still limited to those with more mathematical background knowledge.



The tables of component values for normalised filters do, however, correspond with the illustrated circuit configurations, and permit anyone with a pocket calculator to design a filter.

Normalisation of the filter designs uses a frequency of 1 radian per second to permit the component value calculations to be carried out easily, and scaled for the actual frequency in use. The reason and application of this normalisation is explained lucidly and comprehensibly, right at the start. I have encountered books where this aspect of has been covered this inadequately, potentially leaving the reader confused about much of the rest of the book. This is not the case in this book.

Chapter three covers "Poles, Zeros, and Modern Network Theory". Here is included a better than average exposition of the relationship between pole-zero plots and transfer function. However, I will take my hat off to anyone who can understand the seventh-order inverse Chebyshev pole-zero plot on page 117.

The author has written a commercial filter design program, and a brief chapter is included on this.

High pass, low pass, band pass and band stop filters are covered. Passive and active varieties are explained, and the advantages of each type are made clear.

The 350 pages and 15 chapters are supplemented with a two-page bibliography of further reading, and is well illustrated. The final chapter is an introduction to digital signal processing, although the book is primarily about analogue filter design. Analogue filters are perhaps less glamorous than DSP, and it is true that DSP can do many things which are not possible with analogue filters. However, the reverse is also true, and likely to remain so. At the very least, it is necessary to precede analogue to digital converters with an analogue filter which can prevent aliasing, which occurs when the signal frequency is above half the sampling rate.

In conclusion, this book contains enough design information to permit well-informed home project designers to select filter types, and choose component values for a wide range of purposes. Equally, it covers theoretical material necessary for an understanding of what the filters are doing, and why they work as they do. The level of some of the content will prove difficult for graduate engineers, although the book is useful even for people with a much lower initial level of knowledge.

There were one or two places where extra explanation between steps would have made life easier for me, and I imagine for many other potential readers. However, this is common to all the books I have seen on this subject, and this book makes it clearer than others I have seen. This book will certainly one that I take down from my shelf when I need an insight into filter design.

Brief Mentions

High Performance Loudspeakers by Martin Colloms, 5th Edition; John Wiley & Sons, Chichester. ISBN 0471 970891 3 (paperback).

The new edition of this standard work has new sections including bonding wave panel speakers (NXT), reverse horn speakers (Nautilus) and flat plane speakers; multimedia and home theatre, Dolby ProLogic, Dobly AC-3 THX and multi-channel sound, digital loudspeaker design, digital filters and digital active speakers.

Television Microprocessor IC Data Files by John Edwards; Newnes (Butterworth-Heinemann), Oxford; ISBN 0 7506 3335 2.

A straight reference work of pin function listings for over 200 of the most widely used control microprocessor ICs for television equipment, intended to be useful to workshop and field service engineers where specific model manuals are not conveniently to hand.

Centronics Mini-Lab data logger/controller

Adding more analogue input channels

A 1998 update to the Centronics Mini-Lab, published in ETI Vol. 26 No. 2, to add more analogue input channels. By Dr. Pei An.

This is an update to the Centronics Mini-Lab data logger which appeared in ETI in the spring of 1997. In this article, I will show in principle how to add more analogue channels to the logger, and I will describe a practical circuit which enables the data logger to read 128 analogue inputs.

The Centronics Mini-Lab data logger/controller is a pocket-sized PC-based data acquisition and digital control system giving eight analogue input channels with an 8-bit (or 10-bit) conversion accuracy. The eighth analogue channel is also a high-speed digital input channel. The device also offers five high-speed digital outputs which can be used for controlling external circuits. Because of this unique combination, the data logger can be used not only for data acquisition, but also for control.

The data logger/controller also allows easy expansion of peripheral circuits around the data logger to increase its power. Adding more analogue input channels is one way of doing this. **Figure 1** shows such an expanded system with 128 analogue inputs.

Expanding the inputs

Imagine that you have a switch unit (as in **figure 2**, for example) with 16 switches. One side of each switch is connected to the input voltage. Therefore you could connect 16 analogue voltages to the unit. The other sides of the switches are connected together to form a single-ended output. If you could switch any one switch On at a time, you could connect any one input to the single-ended output. This is the basis of an analogue multiplexer. with 16 switches to control, and using a decoder circuit, you could achieve the necessary level of switch selection using only four selection lines. The input selection chart is given in **Figure 2**.

The Mini-Lab data logger has eight analogue inputs and five digital outputs. If you connect the single-ended output to a single analogue input, you could have eight units connected to the logger. The four switch-selection lines are connected to the digital output lines of the logger (see

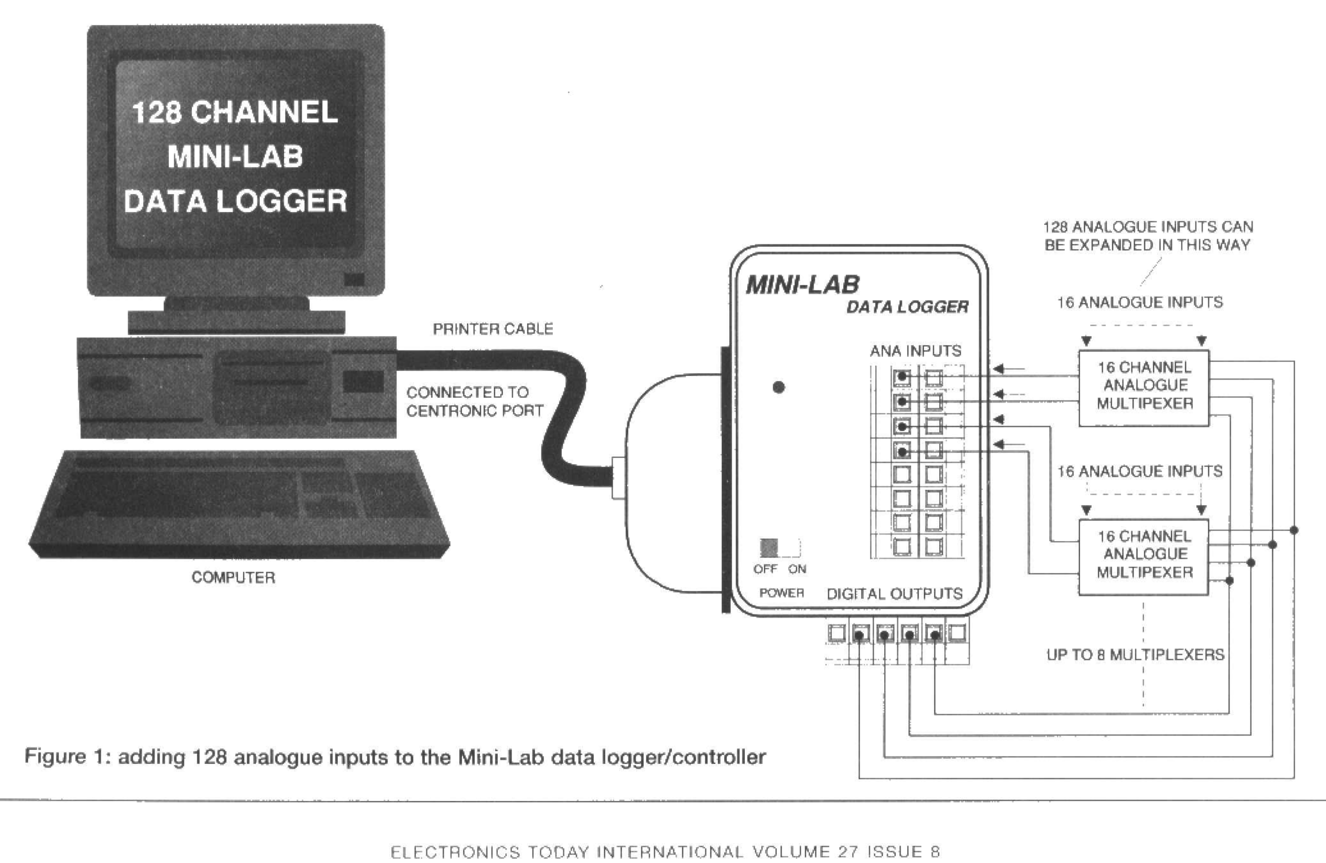


Figure 1: adding 128 analogue inputs to the Mini-Lab data logger/controller

figure 1), giving 128 analogue channels altogether.

An analogue multiplexer

The key component behind an analogue multiplexer is the switch **(figure 2)**. The switches could be mechanical types (such as relays) or semiconductor type (such as analogue switches). Mechanical switches are bulky and consume a lot of power. Mechanical contacts also limit switching speed and are prone to reliability problems. Thus, in most cases they are not used. But mechanical switches have a nearly perfect contact. Because of this, they are used mainly in special cases where ultra high quality switching is required.

Analogue switches are low-power CMOS devices which are compact and inexpensive. There are no mechanical parts involved in switching, so they are more reliable and capable of switching at a much higher speed. They drawbacks are, firstly, that all analogue switches exhibit a small resistance when switched on. This resistance (the 'on-resistance') can be several hundred Ohms. Secondly, a switch on the Off state still produces a small current, called (oddly enough) the 'leakage current', which can be several nanoamps. Finally, CMOS switches exhibit an internal capacitance which limits the frequency band of the input signal. A good mechanical switch, by contrast, has an almost zero on-resistance and no current leakage at all.

Analogue switches come in various packages. Some popular analogue switches are discussed below.

The CD4051 is a low-cost CMOS 8-to-1 analogue switch. **Figure 3a** shows the pin-out of the ic. We can see that a switch is selected using three select lines (A, B and C). Analogue switches can work with unipolar as well as bipolar signals. For the unipolar operation, VDD is connected to the positive rail of the power supply, with VSS and VEE connected to ground. For bipolar operation, VDD is connected to the position rail of the power supply; VEE is connected to the negative rail and VSS is connected to COM. The on-resistance is about 1 kilohm; the leakage current is 100 nA, and the internal capacitance is 10 pF. The CD4067 CMOS 16-to-1 analogue switch **(figure 3b)** has similar electrical characteristics.

Another example is the DG508 8-to-1 analogue multiplexer **(figure 4a)**, one of a family of precision analogue switches. Any

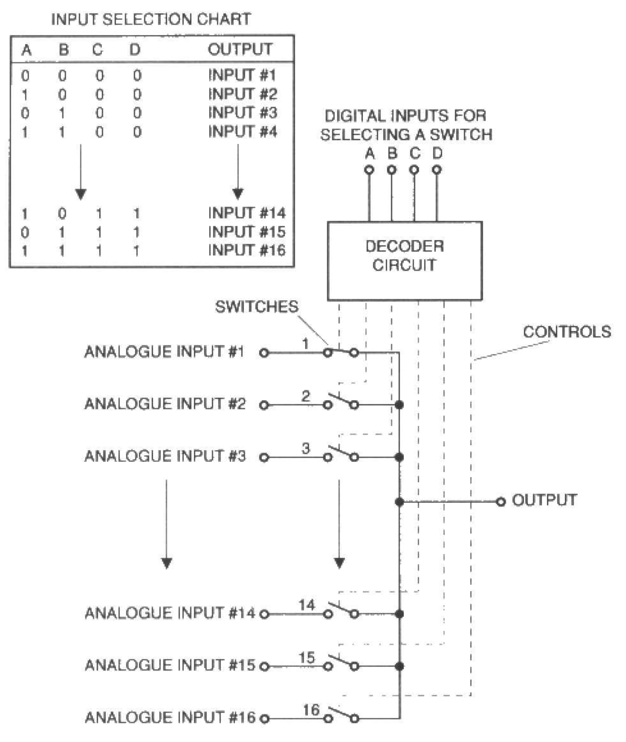


Figure 2: a 16-to-1 switch unit

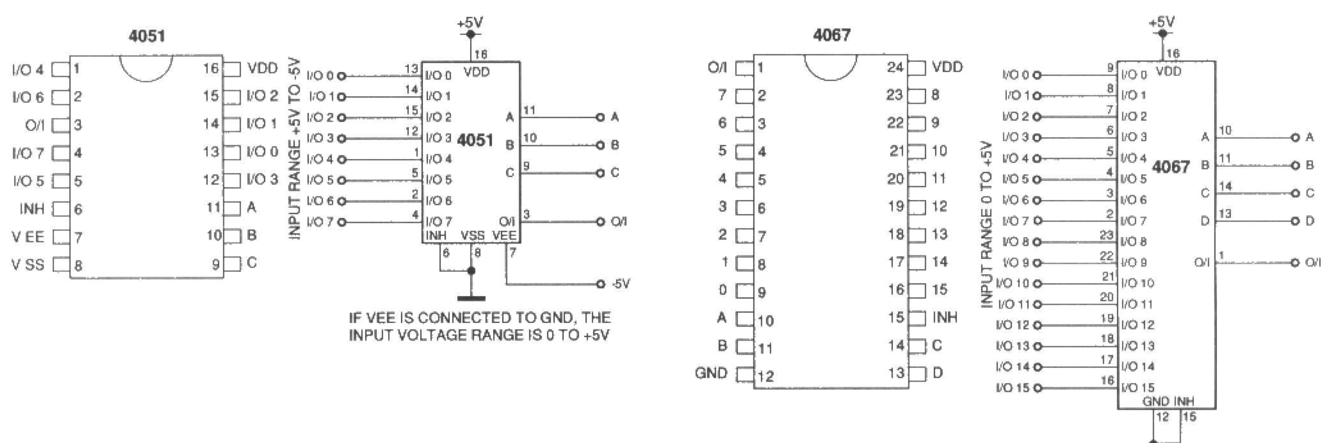


Figure 3: the CD4051 and CD4067 CMOS analogue switches

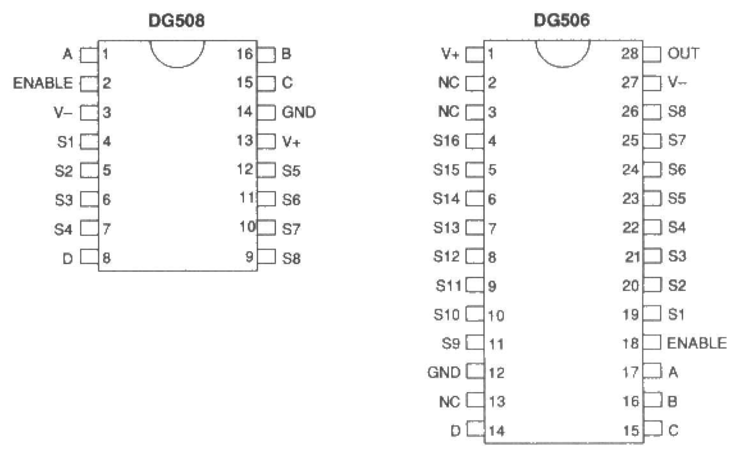


Figure 4: the pin-outs of the DG508 and DG506

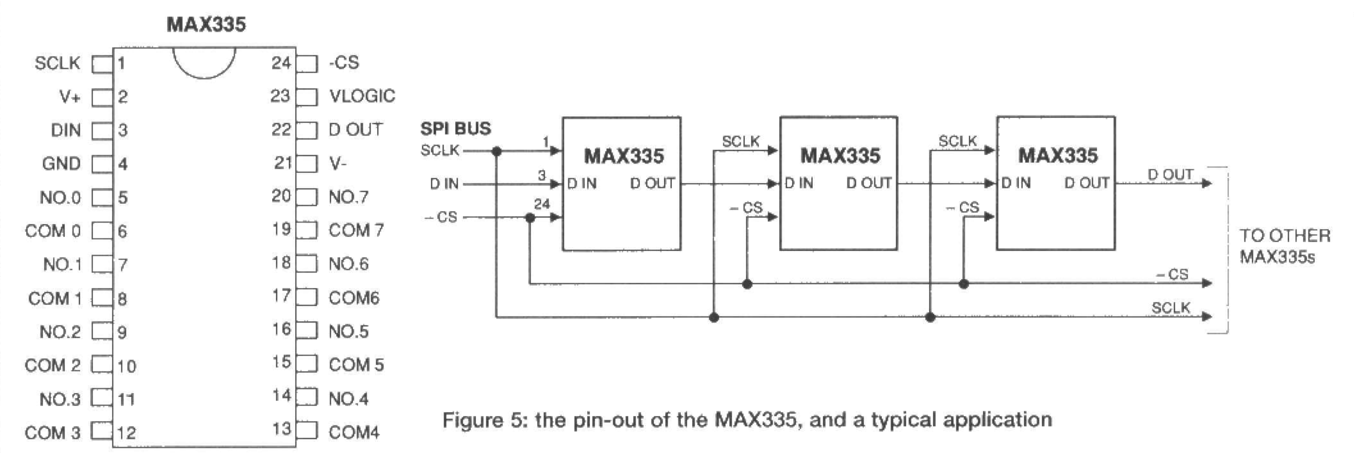


Figure 5: the pin-out of the MAX335, and a typical application

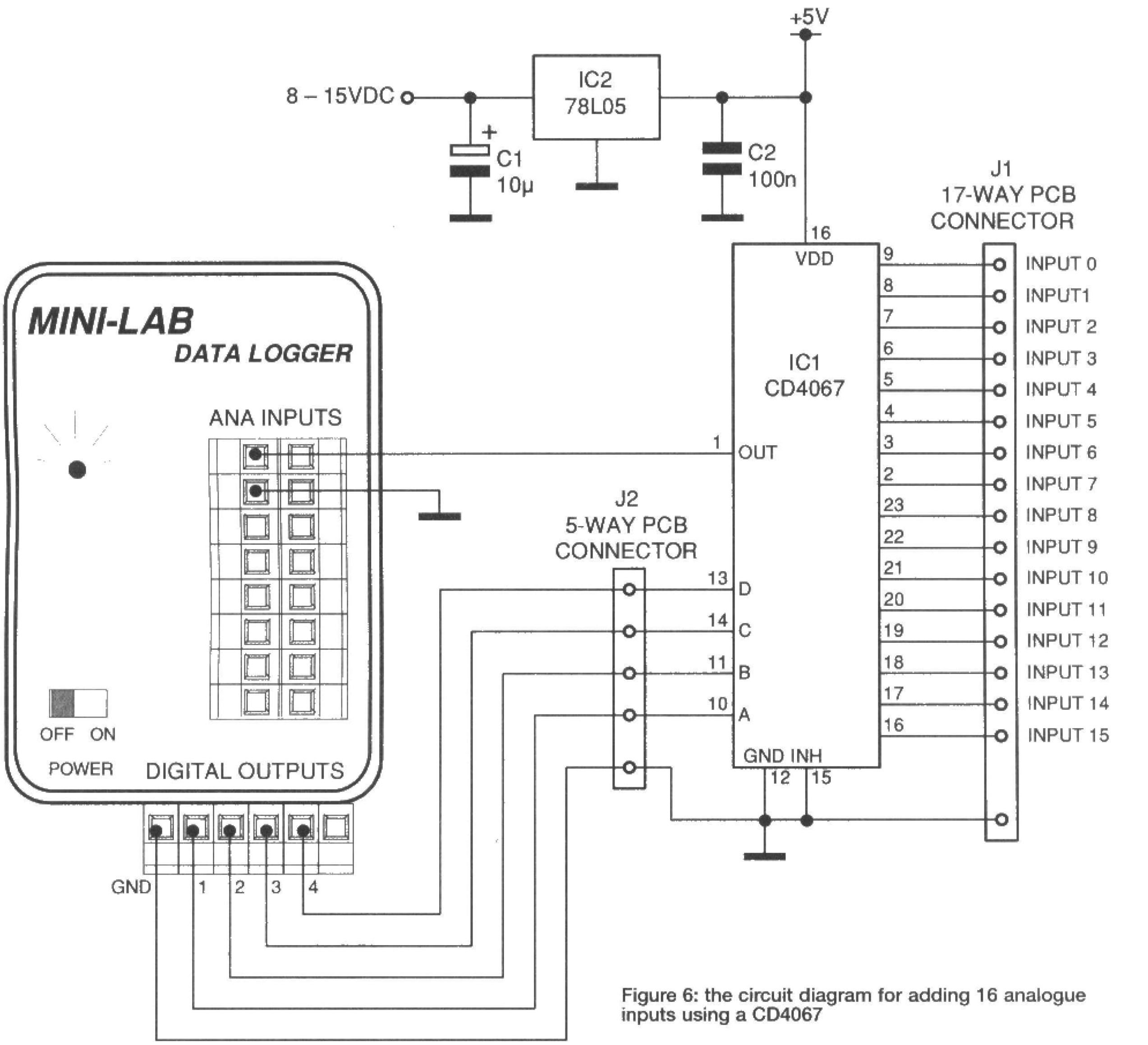


Figure 6: the circuit diagram for adding 16 analogue inputs using a CD4067

switch is selected using three select lines (A, B and C). The enable pin should be high to enable the chip. The on-resistance is about 300R, the leakage current is 0.04 nA and the internal capacitance is 5 pF. The applications for this ic are similar to the CD4051. The DG506 is a 16-to-1 analogue multiplexer **(figure 4b)**, with operation similar to that of the CD4067.

Another example is the MAX335 analogue multiplexer **(figure 5a)**, which uses an SPI serial bus. The selection of analogue switches uses various different interfacing schemes.

The interface in the MAX335 can be thought of as an 8-bit shift register controlled by -CS. When -CS is low, input data appearing at DIN is clocked into the shift register at the rising

edge of SCLK. The data is 8 bits wide (D7 to D0). Each bit controls one of eight analogue switches. At the ninth rising edge of SCLK, the first bit (D7) is shifted out from DOUT. When 8 bits of data have been shifted in, -CS is brought high (SCLK must be low). This updates the new switch status and inhibits further data from entering the shift register. Transitions at DIN and SCLK have no effect when -CS is high and DOUT holds the last bit in the shift register.

A simple daisy-chaining interface is shown in **Figure 5b**. The -CS pins of all the devices are connected together and a serial data bit is shifted through the MAX335s in series. When -CS is brought high, all switches are updated simultaneously. Additional MAX335s can be added. In use, the input analogue signals are connected to pins 0 to 7. Pins COM 0 to COM7 are connected together to form a common output.

Expanding the Mini-lab

In this article, I use the CD4067 16-to-1 analogue switch to demonstrate how the analogue multiplexer is used with the Centronics Mini-Lab. The circuit diagram is shown in **figure 6**. The switch selection inputs A to D are connected to Mini-Lab outputs. The single-ended analogue output is connected to analogue input channel 1 of the logger. The circuit can be constructed on a small piece of stripboard or on a spare piece of PCB material.

The control of the analogue multiplexer is quite simple. Firstly, 4 bits of data are written to the outputs of the data logger to select an analogue switch. Then, data is read from Channel 1 of the data logger.

Figure 6 shows only one analogue multiplexer. Eight CD4067s can be connected to the Mini-Lab. The data selection inputs A to D of the CD4067s are connected to the data logger in the same manner. The analogue outputs from the multiplexer are connected to the data logger's analogue input channels 1 to 8.

Technical support

The complete kit of the Centronics Mini-Lab data logger is available from me. Please direct your enquiries to Pei An, 11 Sandpiper Drive, Stockport, Cheshire, SK3 8UL, U.K. Tel/Fax: +44(0)161 477 9583; e-mail: PAN@FS1.ENG.MAN.AC.UK

PARTS LIST for the Analogue Multiplexer

Parts List Components

IC1	**CD4067 16-to-1 CMOS analogue multiplexer**
IC2	**78L05 +5V 100mA voltage regulator**
C1	**10 uF/16V electrolytic capacitor**
C2	**100 nF ceramic disk**
J1	**17-way PCB connector**
J2	**5-way PCB connector**

A piece of stripboard or pcb material

All components can be obtained from Maplin

This project is an extension to the Centronics Mini-Lab data logger project, ETI Volume 26 No. 2, 1997.

Pushbutton Electronics Security Switch

Lockout security switches for private equipment usually incorporate a bulky keypad. Bart Trepak's ingenious PIC-driven design uses a single push-to-make switch.

There are times when you want to restrict or prevent the operation of electrical equipment by unauthorised people. Computers, printers or photocopiers in an office are an obvious example, while around the home a parent may wish to prevent a child from watching non-stop TV during the holidays, or you may simply want to discourage your sister from borrowing your hi-fi system. Alternatively, a secure on/off switch for a burglar alarm or a vehicle immobiliser may be required.

Whatever the reason may be, the most obvious solution is to fit a key-operated switch to the equipment wired to interrupt the (mains) supply feed to it. As well as not being as cheap as you might think, these switches have other disadvantages, such as the key, which is usually lost or not to hand when it is needed. In an office where many people may be authorised to use equipment, multiple copies of keys add to the risk of some falling into the wrong hands. The prospect of having to add yet another key to an already overpacked keyring is not very appealing.

A digital lock would overcome most of these objections and suitable circuits using a variety of chips from standard CMOS to special ics and even microprocessors have appeared in catalogues and magazines. They have normally been designed for door locks and tend to be either complex or expensive, or both. They often include features such as alarms and anti-tamper keyboard lock-out functions, which are not normally needed for simple applications, but lack others that would be useful. One item which is often almost an afterthought in digital locks is a suitable power supply, often an add-on transformer/rectifier unit which makes the circuit difficult to use as a simple key-operated switch.

Since this design is intended to be mounted in the mains lead to the appliance, this problem is solved by incorporating a simple transformerless mains supply.

This is a Mains project. If you do not have much Mains experience, seek the advice of a constructor familiar with Mains practice before undertaking this type of project.

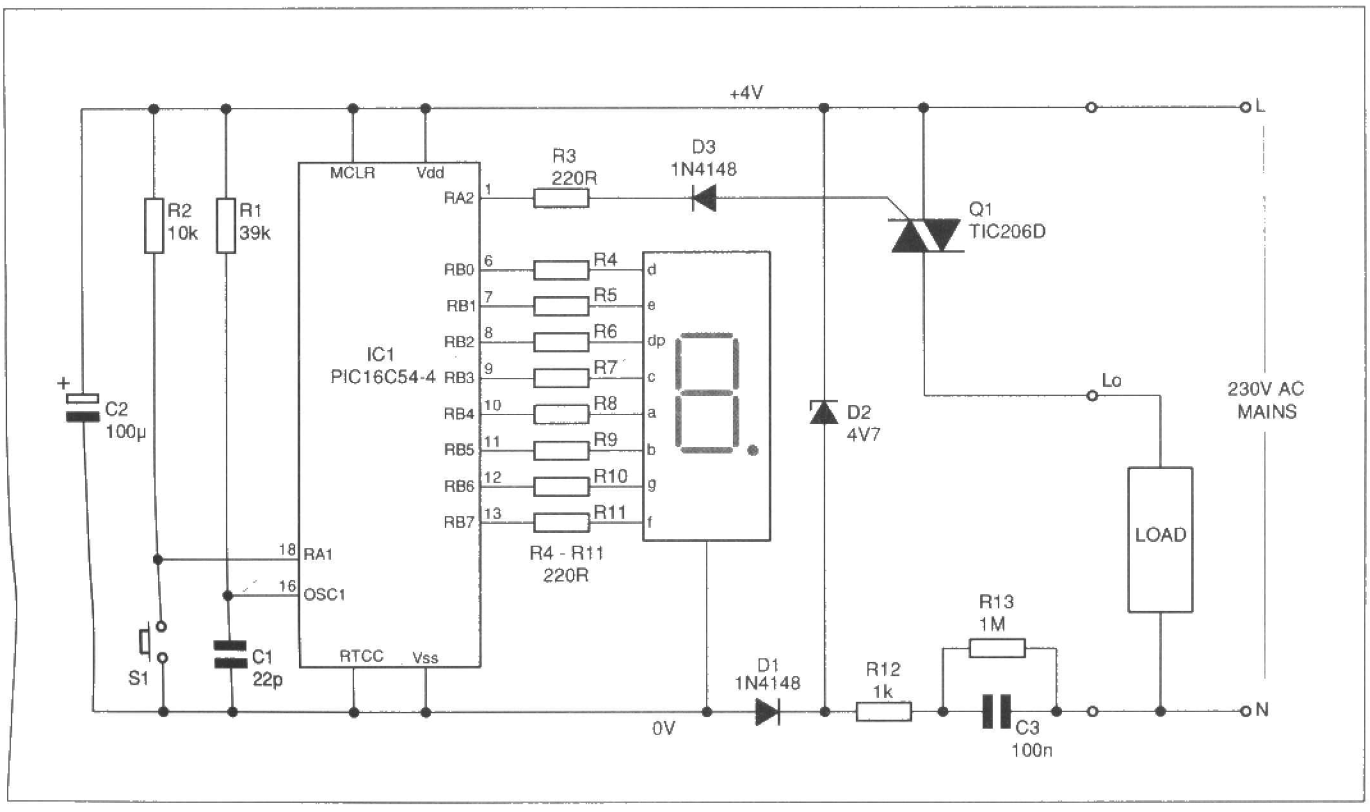


Figure 1: the Electronics Security Switch circuit

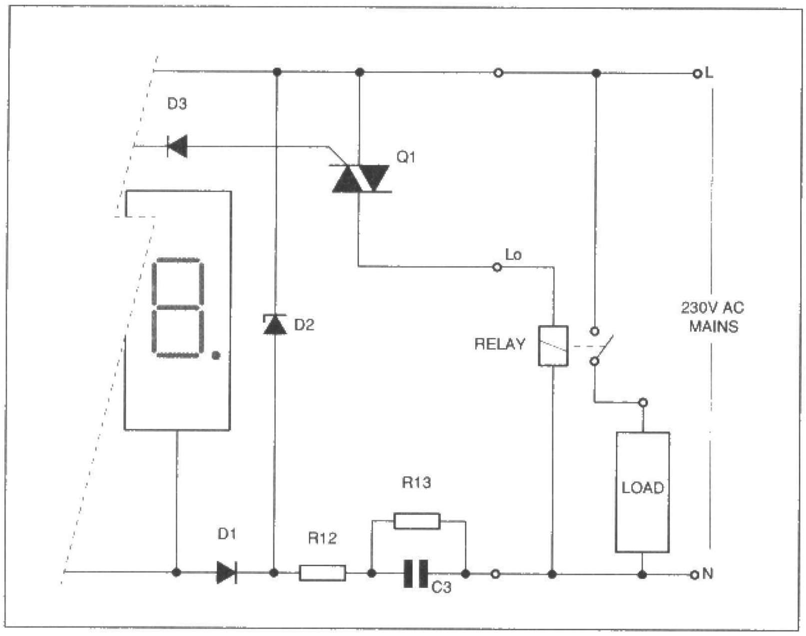


Figure 2: a version of the circuit using a mains relay

Key-bored

Perhaps the biggest drawback to using an electronic lock is the cost and size of the associated keyboard, which can easily exceed the rest of the electronics, making the lock expensive and clumsy compared to a key-operated switch. Commercial digital locks and indeed most of those published in electronics magazines include a keyboard with the ten digits 0 to 9 and sometimes other control keys. What makes this design different is that the boring old keyboard has also been eliminated and replaced by a far more interesting (ie cheaper) push-to-make switch. As the keyboard is normally the single most expensive item in a lock design, this is well worth doing. It also makes the unit smaller and better suited to fitting onto a mains lead. The mode of operation however remains similar to conventional locks, in that four digits must be entered in a specific sequence to switch the output on. To aid the process, a 7-segment LED display is included, and to avoid using a large number of components, the circuit has been designed around a PIC microcontroller. The software is too bulky to publish here, but a programmed PIC is available from the author (see the end of this article).

Having only one push-to-make switch makes the entry of digits unconventional but quite simple. Pressing the button causes the display to light and count from zero to nine continuously and when the required digit is reached, the button is simply released, causing that digit to be "entered" and the display to switch off. This process is repeated until all four digits have been entered. If they are correct, the lock will open and the display will go out. If only part of the sequence or an incorrect one is entered, the output will not switch on. Entering a number also starts a timer which runs for approximately 5 seconds. If no further numbers are entered before this time elapses, the lock is reset so that the next number entered will be treated as the first in a new sequence. In this way each group or part group entered is treated separately and no "enter" key is required.

Once the output is on it will remain on until either the power to the unit is switched off or an incorrect digit or sequence is entered. Thus, if the open code is 3,2, 4, 1 for example and a 2 is entered, the output will switch off as this is not a correct number for the first digit, while entering 3 will have no effect. The output can thus be locked simply by entering any single number which is not the first number in the correct sequence.

Programming

This is of course only half the story as the unit must not only have a code sequence stored in the first place but it must also be possible to change it, but only by those authorised to do so. The micro-controller software has therefore been designed to make this possible but only when the correct sequence has been entered and the lock is open.

To do this, the lock must be placed in the program mode and this is done by first entering the correct open code. Once the lock is open, the key is pressed again (within 5 seconds) and the display will begin to count from 1. Instead of the normal sequence being followed however, a 'P' will be displayed on the first pass after 9 is reached. If the switch is released at this point, the unit will be placed in the programme mode. Note that this only happens the first time around and if the count is allowed to run on, a 0 will be displayed next followed by the normal count (1, 2, etc. through to 9, 0, 1, and so on) and the 'P' will no longer appear. If the switch is to be re-programmed, the complete open code will need to be entered again.

Once the unit is in the programme mode, the first four digits entered will be treated as the new code and stored sequentially in memory. When these numbers are being entered, the decimal point on the LED display will also light to confirm that the unit is in the program mode. After the fourth digit has been entered, the unit automatically reverts to the normal mode and any further display will not be accompanied by the decimal point but treated as a normal entry which, if incorrect, will switch the output off.

Note that, because the new code is stored in ram, it will be erased if the power to the chip is switched off and the open code will revert to the default one which is 1, 2, 3, 4. The default code cannot be changed since it is stored in the START routine which loads the code into the ram at the start of the program execution following a power on reset. This default code should therefore be changed immediately the lock is fitted by entering it and then, when the lock is open, entering the program mode.

Should you forget the default code for some reason however, the unit would become useless as you would then be unable to enter even your own new code and so to avoid this difficulty, a "back door" method of programming is also available.

To use this, the unit must first be powered down fully (switched off and capacitor C2 discharged) and then switched on again. When the key is pressed, the display will show the same sequence as it would if the lock had just been opened so that again the 'P' will be displayed on the first pass. Releasing the switch at this point will switch the output on and place the circuit in the program mode allowing it to be programmed in the normal way. The very low current consumption of the unit ensures that this technique will not work if the power to the unit is simply switched off and on again, because the capacitor C2 will maintain the previously set code for several minutes and prevent a proper power-on reset, thus preventing the preset default code from being loaded into memory.

The circuit

The circuit is based on a PIC16C54 micro-controller and this contains all the usual components of a computer system - an arithmetic/logic unit, a program memory, a data memory and I/O ports together with other features including power-on reset circuit and a watchdog timer to prevent interference from causing the program to crash. This enables the whole circuit to be built around one chip instead of the dozen or so which would be required if a standard logic family were used.

Figure 1 shows the complete circuit of the lock and, as can be seen, all of the logic functions are controlled by the micro-controller IC1 with port A1 functioning as the switch input and A2 the output. In this case it is used to drive a triac Q1 which switches the ac power to the load as required. The whole of port B is used to drive a single digit common cathode LED display, including the decimal point which is used to indicate that the unit is in the "program mode" and a new open sequence can be stored.

The micro-controller clock frequency is set by C1 and R1 and controls the speed at which the circuit operates and the various time delays generated. From the user's point of view, this means mainly the speed at which the LED display counts when S1 is pressed and this may be adjusted by increasing or decreasing the value of R1. With the value specified, this is about 0.5 second per count, so to count up to 8 for example would require S1 to be kept depressed for about four seconds. The counter is arranged to begin from one so that 0 would require 5 seconds. Sequences containing many higher value digits can take rather a long time to enter, with the code 0000 taking around 20 seconds, so it may be that a faster clock speed would be preferred. Too fast a speed would make the unit difficult to use as the digits would change too fast and be missed. Some experimentation may therefore be required, and the value of R1 could be decreased, but should not be made smaller than 4.7 kilohms (which would make it far too fast anyway!).

The dc power for the circuit is derived from the ac mains by the familiar "capacitor dropper" C3 with D2 clipping the voltage at 4.7 volts. D1 rectifies this and C2 smoothes it to provide a 4V nominal supply for the circuit. **Note that this supply is negative as the triac is more sensitive to negative gate trigger currents**. R12 limits the initial charging current to C3 when the circuit is first switched on, preventing damage to D2. R13 serves to discharge C3 when the circuit is switched off, preventing high voltages from appearing on the pins of the mains plug should these be touched after the unit has been unplugged from the mains.

As mentioned, the triac Q1 is used to switch the power to the load and, because of the limited trigger current available, a sensitive gate triac must be used, which limits the triac rating to about 8 amps. Higher power triacs are not normally available in sensitive gate versions. Load currents greater than about 300W (around 1.5 amps) will normally require a heatsink fitted to the triac. If higher currents than this are envisaged, it is perhaps be better to fit a low power triac and use this to switch a relay with a 240V ac coil which would in turn control the power to the load. **Figure 2** shows a suitable arrangement.

The circuit may also be easily modified to operate from dc supplies which may already be available or, if the equipment to be controlled is battery-powered and the zener diode D2 enables almost any voltage supply greater than 3 volts to be used. **Figure 3** shows the arrangement and as can be seen, only C3 and R13 need to be omitted and the negative supply connected directly to R12. The value of R12 may need to be calculated to suit the supply available as shown in the diagram.

When used on a dc supply, the output will probably also need to switch dc, and this may be done by replacing the triac with a suitably rated PNP transistor as shown. Again, higher load currents (or indeed separate dc or ac supplies) may be switched by using a relay with a coil voltage equal to the dc supply voltage. (Remember to fit a diode across the coil if a relay is used to protect the transistor from damage due to back emf.).

Whichever method of switching is used, care must of course be taken to ensure that the unit does not switch its own supply off and if necessary a separate supply may need to be fitted. The current consumption is very low and the unit only draws around 5mA at 9 volts, most of which is due to the zener. This can be reduced to less than 1mA by a suitable choice of resistor R12 so that a battery supply is quite feasible. If the battery voltage is 6 volts or less, the zener diode and R12 may also be left out, reducing the stand-by current to a few micro amps. The minimum voltage at which the circuit will operate is around 3 volts.

Even when building the mains version, it is a good idea to test the circuit at low voltage as this enables the circuit board to be handled safely. This may be done by simply connecting a 9-volt battery to the circuit (+ to L and - to the junction of C3 and R12) with no other modifications being required.

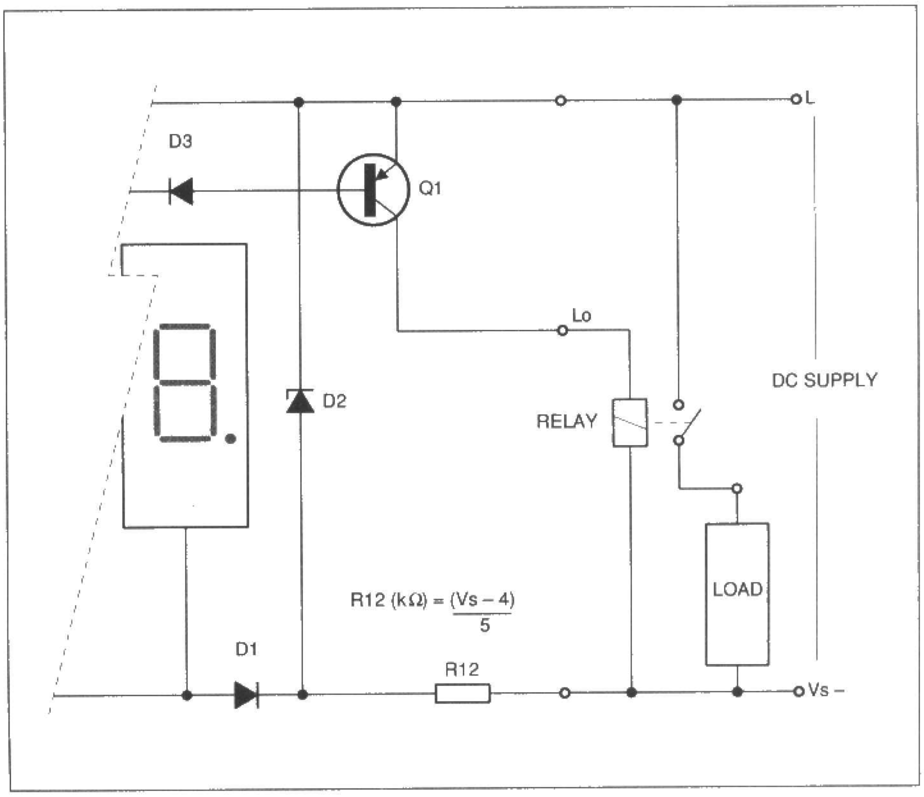


Figure 3: a version of the circuit using a DC supply

Flowchart

Before going on with the construction and testing of the unit, it is useful to examine the structure of the program which is programmed into the micro-controller to enable it to carry out this function. This is shown in simplified form in **figure 4** as a flowchart. No great effort was made in minimising the code as the program easily fits into the available program memory on the PIC16C54.

When power is first applied, the program jumps to the label START and executes the set-up routine which initialises the various registers into the states required, including the default open code. It then goes on to the label marked BEGIN which is the beginning of the main program.

The number to be displayed is held in a register called KEYCTR (KEY CounTeR). The program tests input port A1 to see if the switch is being pressed. If it is not, KEYCTR is reset to zero and the subroutine TIMR (timer) is called. This is the second part of a larger subroutine called STIMR which starts the 5-second timer by loading two registers (DYCTR1 and DYCTR2) and setting a bit (bit 0) in a register called FLAG to show that the timer is running. TIMR simply decrements these two registers each time it is called, and when they have both reached zero (which depends on the numbers stored initially and the speed of the system clock) resets bit 0 in the FLAG register. The program can therefore test this bit at any time and determine if the 5-second time has elapsed or if it is still running without devoting all of its time to this.

Subroutines are simply self-contained pieces of program code which perform a function required often in a given program . They must be given a unique label and must end with the RETLW instruction, which tells the processor to return to the next instruction after the point from which the subroutine was called and place the number (which can be expressed in binary or hex) associated with the instruction in the W register. This number may or may not be utilised in the next instruction depending on what the program is required to do.

This technique is best understood by considering the DISPLY subroutine is used for driving the LED display, which is shown in the flowchart of **figure 5**. When called, this places the value found in KEYCTR into the W register and calls another subroutine called DECODE. This subroutine effectively decodes the binary number in KEYCTR to a seven-segment bit pattern suitable for driving the LED display. This is done by adding the value now in the W register to the Program Counter which causes the program to jump to a location depending on the number originally found in the KEYCTR register. Thus if KEYCTR contained the number 5, then 5 would be added to the program counter and the

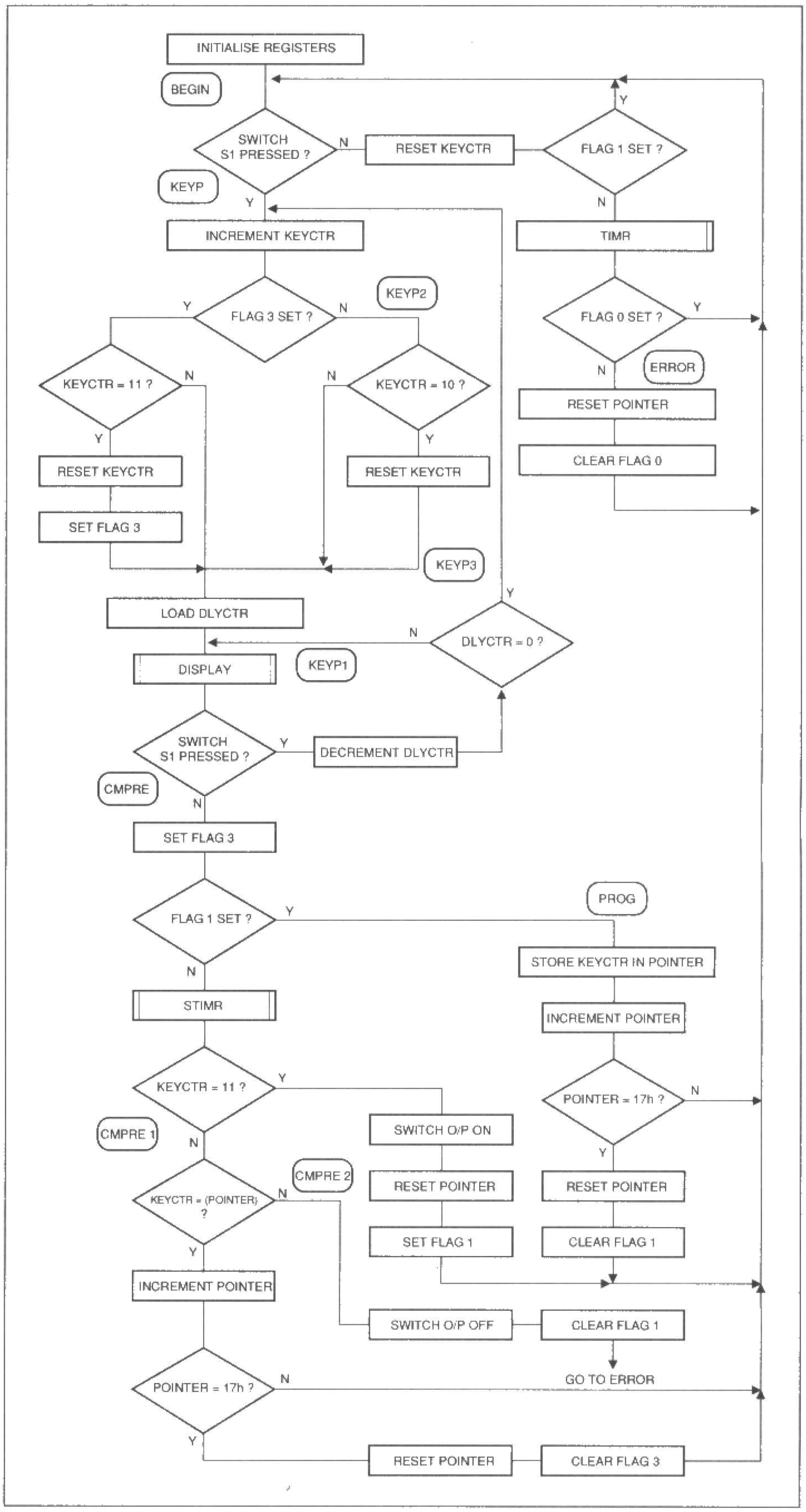


Figure 4: the Electronics Security Switch flow chart

program would jump to a location where it would find the instruction "retlw 0D9h". This would cause the program to return to the point from which this subroutine was called, that is, the fourth line in the DISPLY subroutine, and execute the instruction found there to transfer the new value (D9) to port B. The number D9 in binary, as shown in **figure 6**, has just the correct bits set to light segments a, c, d, f and g and display the number 5 on the LED display. The program then checks to see if the unit is in the PROGRAM MODE, in which case the decimal point is also lit and after a short delay (made up of five "nop" instructions) port B is cleared and the display is switched off and the program returns to the location after the point in the main program from which the DISPLY subroutine was called. Thus by using the instruction "call DISPLY" at any point in the main program, the value in the KEYCTR register will automatically be displayed on the LED display. But, as they say, we digress ...

On returning from the TIMR subroutine, the flag bit is checked and if the timer is still running the program will loop back to BEGIN and start again. Since the key has not yet been pressed, the timer will not be running anyway, so that the program will follow the other path and reset the timer and also the "pointer" which is in fact the FSR (file select register) which is used to point to the next digit in the open sequence. The four digits are stored in four registers labelled CODE1, CODE2, CODE3 and CODE4, and since no digits have yet been entered into KEYCTR the pointer register will be reset to point to CODE1. The contents of these locations are initially loaded by the program and will therefore contain the default values of 1, 2, 3 and 4. It may seem strange to keep resetting the timer and the pointer when both are reset anyway, but it is sometimes necessary to do this once the switch has been pressed, and it simplified the program by making it unnecessary to write this sequence of instructions again elsewhere.

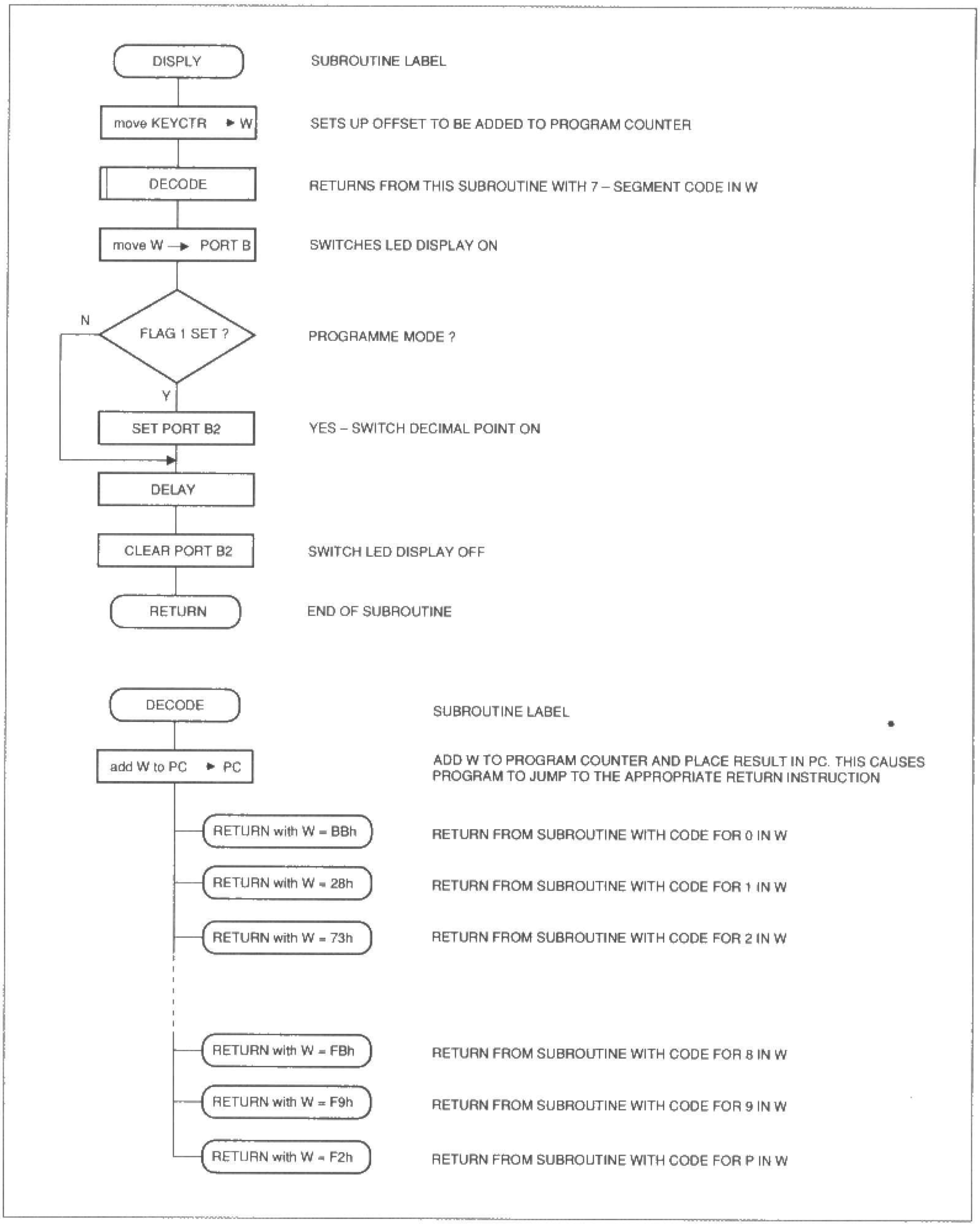
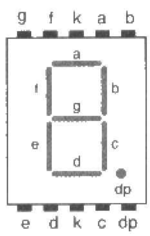


Figure 5: the LED display and Decode subroutines

When the switch is pressed, the program jumps to label KEYP where the instruction "incr KEYCTR" is located. This register is now incremented, checked to see that it has not over-run to ten (or 11 decimal if the letter 'P' is to be displayed) in which case it is reset to zero and the subroutine DISPLY called which displays the current value in KEYCTR as described. The input port A1 is again checked for a key press and if it has been not been released, a short delay loop of about 0.5 seconds is initiated based on the counters DLCTR1 and DLCTR2 before the program jumps back to KEYP to increment KEYCTR again. Note that the DISPLY subroutine is called from within this delay (program route through KEYP1) to ensure that a continuous display is obtained while the switch is depressed. The KEYCTR register is therefore continuously incremented and displayed while the key is pressed and reset to zero when it overruns.

When the key is released, the program jumps to CMPRE where it checks if the unit is in the normal or program mode (by checking the FLAG register) and if the former, compares the number reached in KEYCTR with that in the register pointed to by the pointer register FSR. Here the decision is made on whether the correct digit had been entered, in which case the FSR register is incremented to point to the next digit or the unit reset, before the program loops back to BEGIN. Since the first code is stored in CODE1 (defined as address 13h), the last code digit in the sequence will be at address 16h. Therefore, if the FSR increments to 17h, four correct digits must have been entered, the output is switched on and the pointer and flags reset.



DISPLAY	SEGMENTS LIT	PORTB OUTPUT (BINARY)	HEX
0	a,b,c,d,e,f	1011 1011	BB
1	b,c	0010 1000	28
2	a,b,d,e,g	0111 0011	73
3	a,b,c,d,g	0111 1001	79
4	b,c,f,g	1110 1000	E8
5	a,c,d,f,g	1101 1001	D9
6	a,c,d,e,f,g	1101 1011	DB
7	a,b,c	0011 1000	38
8	a,b,c,d,e,f,g	1111 1011	FB
9	a,b,c,d,f,g	1111 1001	F9
P	a,b,e,f,g	1111 0010	F2

NOTES:

1 – CONNECTIONS TO SEGMENTS AS SHOWN IN FIGURE 1 ie. B0 – SEGMENT d, B1 – e, B2 – dp etc.

2 – BINARY AND HEX CODES SHOWN WITH dp OFF (OUTPUT B1 = 0)

3 – k IS THE COMMON CATHODE CONNECTION

Figure 6: display printouts and codes

The steps executed when programming a new sequence can be followed from the flowchart at the label PROG where, instead of comparing the value in KEYCTR with that in the memory location pointed to by the pointer, the current value in KEYCTR is stored there. Again, when four digits have been entered, bit 1 in the FLAG register is cleared ending the program mode. Many of the branch decisions are made, depending on the current contents of the FLAG register and so the significance of the bits in this register are shown in **figure 7**.

Construction and testing

The circuit is built on a printed circuit board which, when mounted in a small plastic case, can be fitted onto the mains lead of the equipment concerned. The layout of the board is shown in **figure 8**, and I recommend that this is the method of construction used, as mains voltages are present on the board. None of the components is critical except **the capacitor C3, which must be suitably rated for mains operation (class X 250V ac working) and the triac which must have a maximum trigger sensitivity of 5mA and a voltage rating of at least 400 volts**. Note that the micro-controller is a CMOS device and although quite robust electrically, the use of a socket is strongly recommended.

Construction is quite straightforward, with all the components being mounted on the PCB. Depending on the plastic box selected, it may be easier to use a panel-mounted switch which would then be connected to the board by flying leads. A four-way terminal block should also be connected to the board by flying leads soldered to pins at the appropriate points (L, N and Lo) on the board to simplify the connections to the mains. **Although the circuit itself is not earthed (and must not be) the fourth connector on the block should be used for the Earth as a through connection to the appliance as shown in figure 9. Remember that the unit is connected to the mains so that both input and output leads should be firmly anchored to the box using strain relief bushes.** The input lead will probably be terminated in a suitable mains plug but **the output lead must be wired directly to the appliance or terminated in a non-standard mains socket. The PCB must not be mounted with metal bolts to avoid the danger of shorting to a live part inside the box. Use insulated mounting materials.** If a relay is to be used, this will also have to be mounted "off the board", insulated and secured to the box in some way. A suitable hole will also be required for the display and as this is rectangular in shape this will need to be made using a file if a suitable punch is not available. Ideally a clear or red tinted window should be fitted over the display but this may be omitted if the hole is cut accurately.

Alternatively, if the appliance with which the unit is to be used is large enough, the PCB assembly (and relay if used) could be mounted inside it and wired to interrupt the mains feed with only the push button and display mounted on a panel. Great care must be taken to insulate the board from the case and that live parts are spaced well away from anything that might short with them in the course of use.

Once assembly is complete the unit can be tested. As mentioned, this is best done using a low voltage supply with the positive side connected to L and the negative to the junction of R12 and C3/R13 and it is probably easiest to solder two temporary leads to these points on the printed circuit board. To simplify the procedure, an LED may also be connected in place of the triac between the gate and MT1 terminals (that is, the two outer ones) with the cathode nearest the edge of the board. This will enable the output status of the lock to be observed without the need of a multimeter.

Without the chip plugged into its socket and a supply of between 5 and 15 volts connected to the leads, check that the voltage between pins 5 and 14 of the socket is between 3 and 5 volts with pin 14 positive. If all is well, switch off the supply and discharge C2 by shorting out its pins. Plug in the chip ensuring that it is inserted the correct way around (notch furthest away from the display) and switch on.

The LED connected to the output and the display should both be off. Press the switch and the display should light with '1' followed a short time later by 2, 3 and so on until 9, P and 0 is reached. The sequence should repeat for as long as the switch is pressed except that on subsequent occasions the 'P' will not be displayed. When the switch is released, the display should go out. The original default code stored in the chip is 1,2,3,4 and this should be entered by holding down the switch each time until the desired number is displayed. If the numbers are changing too fast to enable you to do this, increase the value of R1. When the switch is released when the display reads 4 then, assuming the previous three digits have been entered correctly, the output LED should light. To switch off the LED, any digit other than 1 should be pressed.

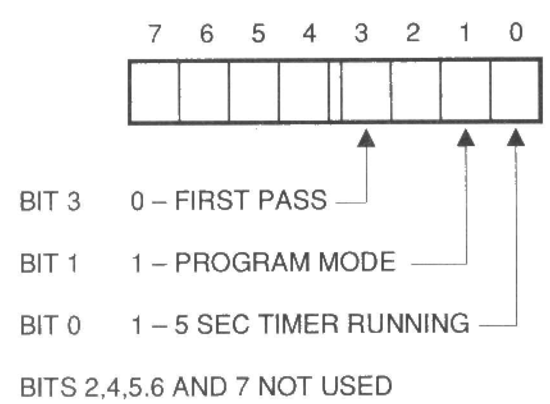


Figure 7: the flag register bit assignment

Once you have done this, a new open sequence may be programmed into the device. Enter the 1,2,3,4 sequence again and when the LED switches on, press the switch again and release it when the display shows the letter 'P'. Enter the numbers of your new sequence in the same way and note that the decimal point is now lit to signify that the digit will be stored. The output also remains on irrespective of which digits are entered. After the fourth digit is entered, the next digit will not display the decimal point but will be treated as a normal entry which, if it is not the correct number (that is, the first digit of your new code sequence) will cause the output to switch off. Check by entering the old sequence to ensure that this is no longer valid and the new one to ensure that it has been stored.

If all is well, replace the output LED by the triac and assemble the unit in its box as shown in **figure 7** with the mains input lead terminated in a fused three pin mains plug. The above tests may be repeated with the unit connected to the mains and a small table lamp as the load. Once the above tests have been completed, the target appliance should either be wired directly to the terminal block in the box, or the output lead and the appliance fitted with a non-standard mains plug and socket connector to prevent the unit from simply being by-passed by plugging the target appliance directly into the mains. If possible, the best solution would be to fit the complete unit into the appliance. **Either way, remember to disconnect the device from the mains before attempting any wiring or re-wiring**.

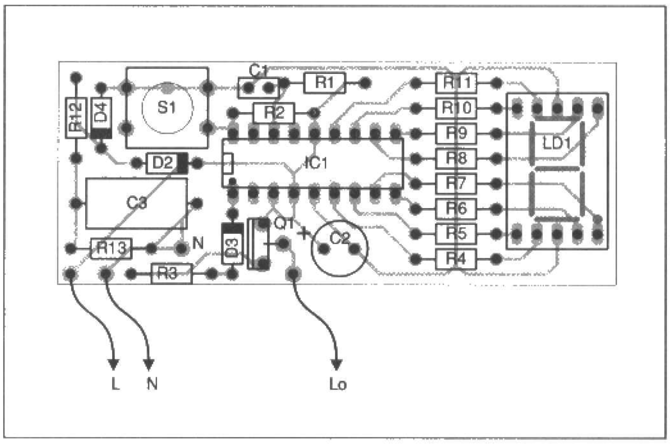


Figure 8: the Security Switch component layout

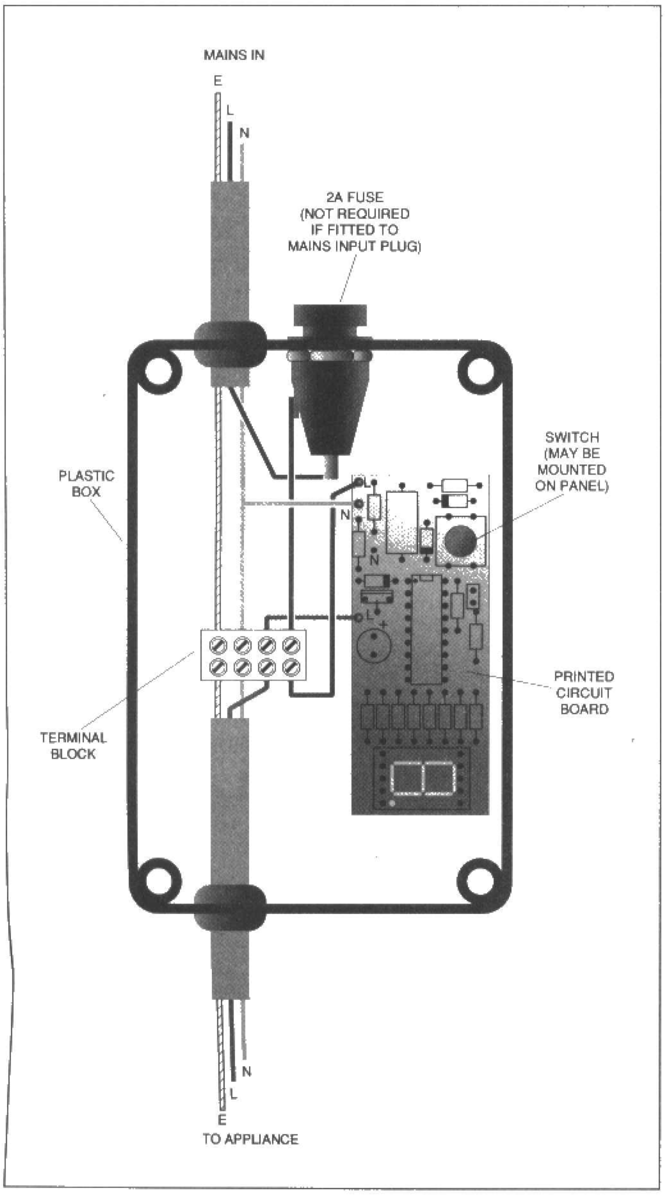


Figure 9: internal wiring of the unit

PARTS LIST for the Electronics Security Switch

Resistors

R1	39k
R2	10k
R3 - R11	220R
R12	1k
R13	1M

Capacitors

C1	22pF ceramic
C2	100uF/16V electrolytic
C3	100nF/250Vac Class X

Semiconductors

IC1	PIC16C54-4 Pre-programmed microcontroller (Order as PIC16C54-4K)
Q1	TIC206D 3A/400V triac
D1, D3	1N4148 diode
D2	4V7/400mW zener diode
LD1	LED display CC

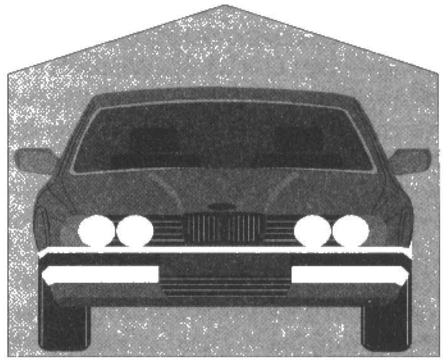
Miscellaneous

Box, push-to-make switch, terminal block, printed circuit board, fuse holder, cable, wire, strain relief bushes etc. as required.

The pre-programmed PIC micro-controller is available from the author at £9.50, or the software only on a 3.5-in disk for £5.00 including UK postage (Overseas orders please add £2). Send cheques/postal orders/overseas Bankers Drafts, and all enquiries relating to the software, together with your name and address stating clearly the project you are building to: B. Trepak, 20 The Avenue, London W13 8PH. Mail order only.

Save Your Garage

Easy Parker



Is your garage a bit on the short side? This sensor by Terry Balbirnie should mean fewer buckled bumpers

Modern houses in the UK often have garages a tad too short for comfort, and the long ones are increasingly full of the household utilities to make up for tiny kitchens. Parking an average-sized car in one (when there is room for a car at all ...) requires considerable skill. Go too far and you hit the wall (or the washing machine, or even the washing) and possibly damage the car, or at least embarrass yourself severely. Not far enough and you won't be able to close the garage door. The Easy Parker circuit helps you to park correctly with confidence. No more bent bumpers, and no more timid parking where you are left pushing the car the last few inches.

Traffic lights

This system consists of two units housed in small plastic boxes. The first is attached to the garage wall near floor level. It has a sensor wire projecting out of the top and leaning forward by about 30cm (1 ft) from the wall. The end of the wire is arranged to be at bumper level or the height of some other fixed part of the car, such as the number plate, so that it is nudged when the car is driven into position. The tip of the wire may be protected using a plastic sleeve or some soft material so that it will not scratch the surface.

The second box has a row of three large light-emitting diodes mounted on the front - one red, one yellow and one green, rather like our traffic lights. It also contains the main circuit panel and a battery pack. This box is attached to a wall at windscreen height. The two sections are linked using a piece of light-duty three-core wire. It is not necessary for the indicator unit to be mounted on the same wall as the sensor, as long as they are linked. If you prefer to reverse the car into the garage, it may be more convenient to mount it on the side near the driver's window.

In use

To use the Easy Parker, you (and your car) approach the sensor slowly. Soon after the car touches the wire, the green LED will come on. This is the signal to move very gently. Then the yellow, and then the red ones operate. This is the signal to stop. The LEDs go off after a preset time which may be anything from ten seconds to over a minute. This type of staged warning is very effective and enables even a novice driver to park the car without difficulty. The sensor is spring loaded so that when the car is driven out of the garage, the wire returns to its former position ready for the next time.

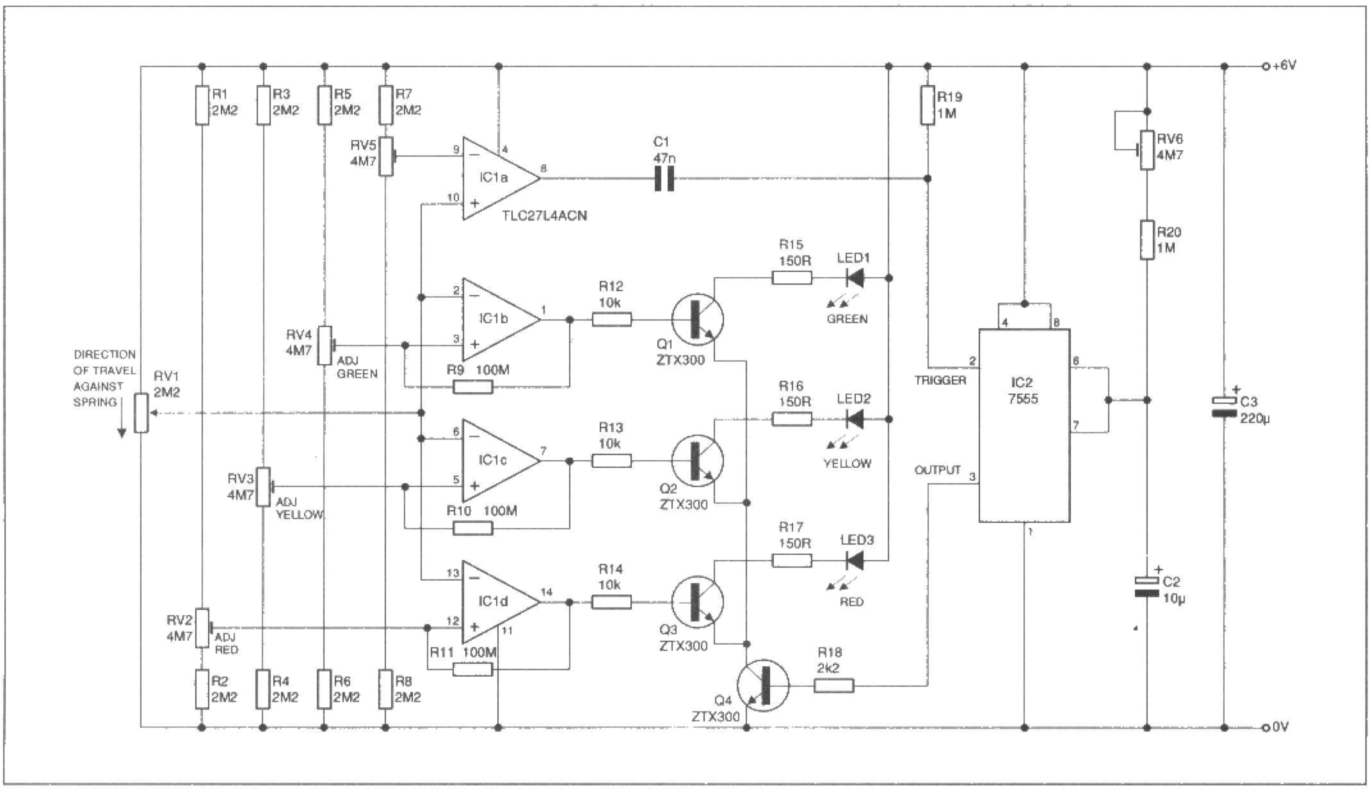


Figure 1: the Easy Parker circuit

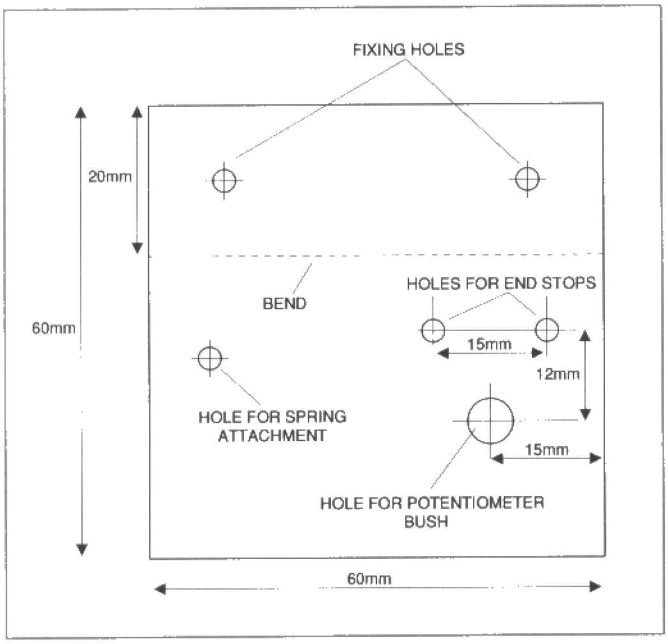


Figure 2: the layout and suggested measurements for the sensor panel

The battery pack in the prototype used four AA cells giving a nominal 6V supply. The circuit imposes a continuous current drain of some 100uA, and the specified alkaline cells will last about a year in normal use. The exact life will depend on how often the circuit is used and the LED operating time. With all three LEDs on and with fresh batteries, the current requirement will be about 80mA.

It is recommended that you read through construction of the sensor section before deciding to build this project. Although by no means difficult to make, you must ensure that you have the necessary tools and materials to hand. You should also check that your car and garage arrangements are suitable.

The circuit

The circuit is shown in **figure 1**. The mechanics will be described below. For now, bear in mind that when the sensor wire is pushed against the force of the spring, it rotates the sliding contact of potentiometer RV1, with a downwards movement. RV1 is across the 6V supply. As the wire is moved to the car's final parking position, the voltage at the sliding contact will fall. About one-quarter of the track travel is used, and this will be arranged to be near the centre, giving a voltage change from about 3.75V to 2.25V. RV1 has a very high resistance to minimise the continuous current flowing through it from the supply.

IC1 is a quadruple op-amp containing four identical units, A, B, C and D. The ic has been chosen for its very small quiescent current requirement (about 40uA total). This is important, as it will be drawing current from the battery pack continuously whether the car is parked or not. I therefore strongly advise using the ic specified. Three of its sections (B, C and D) are used to control the green, yellow and red LEDs respectively. Op-amp A triggers the monostable which switches off the display after a preset time.

Input voltages

Before the car is moved into position, the voltage at RV1 sliding contact is approximately 3.75V in its rest position. Consequently, the non-inverting input of op-amp A (pin 10) and the inverting inputs of op-amps B (pin 2), C (pin 6) and D (pin 13) are all at this voltage.

The inverting input of op-amp A, (pin 9) and the non-inverting inputs of B, C and D (pins 3, 5 and 12 respectively) receive various fixed voltages depending on the adjustment of preset pots RV2 to RV5. These work with resistors R1 to R8 to form a set of potential dividers. The fixed resistors narrow the range of adjustment of the presets to about 1.5V to 4.5V - note that this is more than that given by RV1. Like RV1, RV2 - RV5 and R1 - R8 have very high values to reduce the continuous current drawn. Virtually no current flows into the op-amp inputs due to their exceptionally high input impedance. The total current drawn by all the potential dividers, including RV1, is about 5uA.

As an illustration: suppose RV2 to RV5 are adjusted so that 3.7V is applied to op-amp A, 3.2V to B, 2.7V to C and 2.2V to D. If the non-inverting input voltage of an op-amp exceeds its inverting one, the output will be high (near positive supply voltage). Otherwise, it will be low (0V). Since the non-inverting input voltage of op-amp A (3.75V) is greater than the inverting one (3.7V), the output (pin 8) will be high. With B, C and D, the inverting inputs have the greater voltage, so these will be OFF with pins, 1, 7 and 14 low. There will be no drive to the base of transistors Q1, Q2 and Q3 and the LEDs in their collector circuits will remain off.

Sequence of events

As the car moves into its parked position, the non-inverting input voltage of op-amp A falls below the inverting one and pin 8 goes low. This applies a momentary low pulse via capacitor C1 to the trigger input (pin 2) of IC2. This is a timer configured as a monostable and, once triggered in this way, its output (pin 3) will go high for a certain time then revert to low. The period is determined by C2, R20 and preset RV6. With the values specified, the operating time can be adjusted between about 10 seconds and more than a minute. This can be increased by raising the value of C2 if required. Note that IC2 must be CMOS as specified to minimise its standby current requirement. The monostable enables operation of the LEDs in a way that will be explained presently.

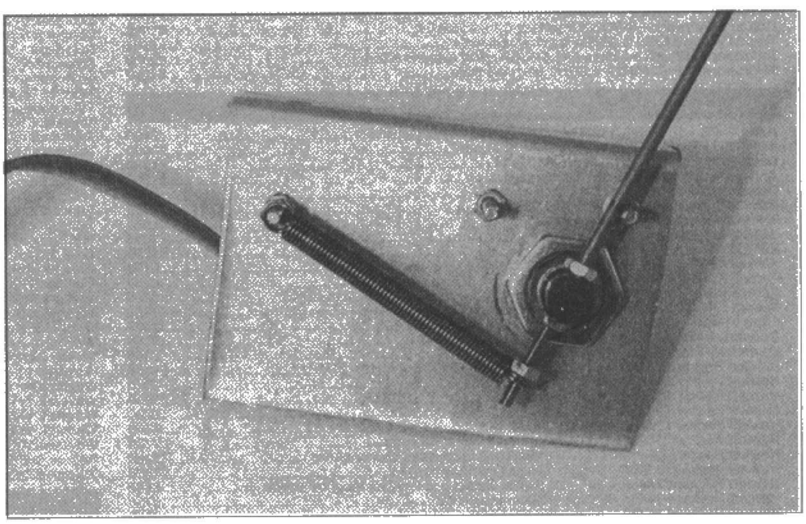


Photo 1: the lower end of the sensor mounted through the pot spindle and sprung. This example is threaded, but fixing can be done with epoxy

Operating lights

Imagine the emitters of Q1, Q2 and Q3 are at 0V (as they will be while the monostable is timing). As the car moves further and the voltage at RV1 sliding contact falls, the inverting input voltages of op-amp sections B, C and D will fall below the respective non-inverting values in turn. As the outputs go high, Q1, Q2 and Q3 receive base current which is limited to about 500uA by R12, R13 and R14 respectively. Collector current will then flow and the green, yellow and red LEDs (LED1, LED2, LED3) will operate in that order.

Op-amp sections B, C and D (but not A) have positive feedback applied via R9, R10 and R11 respectively. This sharpens the switching action by making the "on" position of RV1 not quite the same as the "off" one. If you are unable to obtain the specified very high value resistors, they could be omitted without much difference unless the car moved very slowly, when the LEDs would flicker a little at the switching points.

The operating points will remain the same as the batteries age and the terminal voltage falls, because all the op-amp inputs are derived from potential dividers. They will therefore all fall together and the relative conditions will remain the same. When the LEDs become too dim to see easily, it will be time to replace the batteries.

Down the drain

To reduce battery drain, the LEDs should remain ON no longer than necessary, otherwise they will drain the batteries in a short time. The monostable switches them off after a preset time. Before the car has moved up to the sensor wire, op-amp section A output will be high. The monostable is triggered by a low pulse. IC2 pin 3 will remain low, Q4 will receive no base drive and nothing will happen. IC1 trigger input is maintained in a normally high state via R19 which prevents possible false operation.

However, when the car moves the wire slightly, op-amp A switches off, pin 8 goes low and triggers the monostable. The output goes high for the preset time. During this time, high pin 3 causes Q4 to turn ON and its collector to go low. This sends Q1, 2 and 3 emitters low, enabling the LEDs. When the monostable times out, the LEDs go OFF.

Construction

Do the sensor section first. This involves some metalwork. You will need a piece of sheet aluminium say, 0.8mm thick and about 60mm square. A piece from an old project box could be used or you could buy some from a component supplier. You will also need a piece of stiff metal wire about 300mm (1ft) long or more, about 2mm diameter, for example in brass or mild steel. Thin brass rod is widely available, including some component suppliers, or you could use a welding or brazing rod (as in the prototype). Or try your local garage, hardware shop or college. Coathanger wire is about 2.5mm in diameter, strictly too thick for the job, unless you can find a flimsy one. You will also need a small steel extension spring. The one in the prototype was 32mm long, diameter 4mm, although this is not critical. You could probably use an elastic band but this is not really strong enough and would need to be replaced fairly often.

It would be useful if you had access to a set of small taps and dies but this is not essential.

Details of the sensor plate are shown in figure 2. Cut out the piece of aluminium and bend it as shown. Drill the large hole for the potentiometer bush and the five small ones as indicated. The position of the hole for spring attachment will depend on the length of your spring. None of the dimensions is strict - they are the ones used in my prototype.

On the panel

Grip the spindle of potentiometer RV1 in a small vice and drill a small hole about 5 mm from the fixing bush (see **photo 1**). This should either be a tight push fit for the wire, or both the hole and the end 20 mm of the wire should be threaded. If you have access to a set of small taps and dies, this would be the best method.

Mount RV1 using a nut on each side of the panel, only hand tight for the moment. The bush must protrude through the hole by only a small distance. Bend the upper tip of the wire into a right to give a protruding end to contact the car. If the lower end has been threaded, screw a nut on the wire as far as it will go. Next, screw the wire into the hole in the pot spindle until about 10mm protrudes from the other side. Attach the other nut. Adjust the tip of the wire so that it is parallel with the pot spindle, then tighten the nuts firmly.

However, if you (like many people) do not have access to taps and dies, you can secure the wire in the spindle hole using quick-setting epoxy resin adhesive or in some other way. Whatever method is used, make sure that the wire is held securely so that it will not come out in service. Attach thin bolts about 12mm long through the three small holes in the large face of the panel and secure them. The two bolts nearest the potentiometer bush act as end-stops for the wire, and the third is used to attach the return spring. In the prototype, end stops limited movement of the wire to a 60degrees of arc approximately (the tip moved about 30cm from side to side).

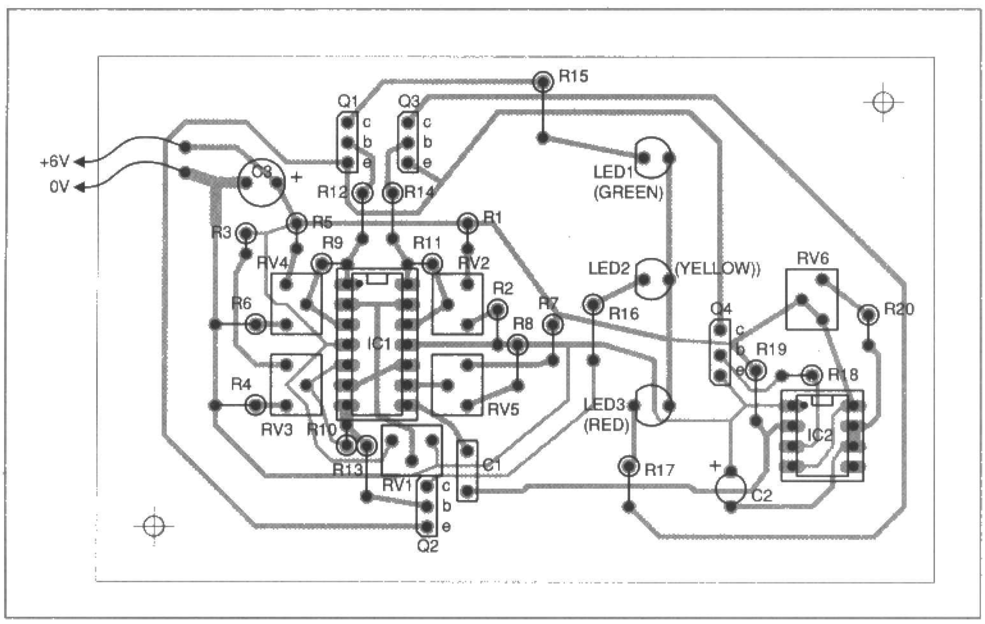


Figure 3: the component layout for the main unit

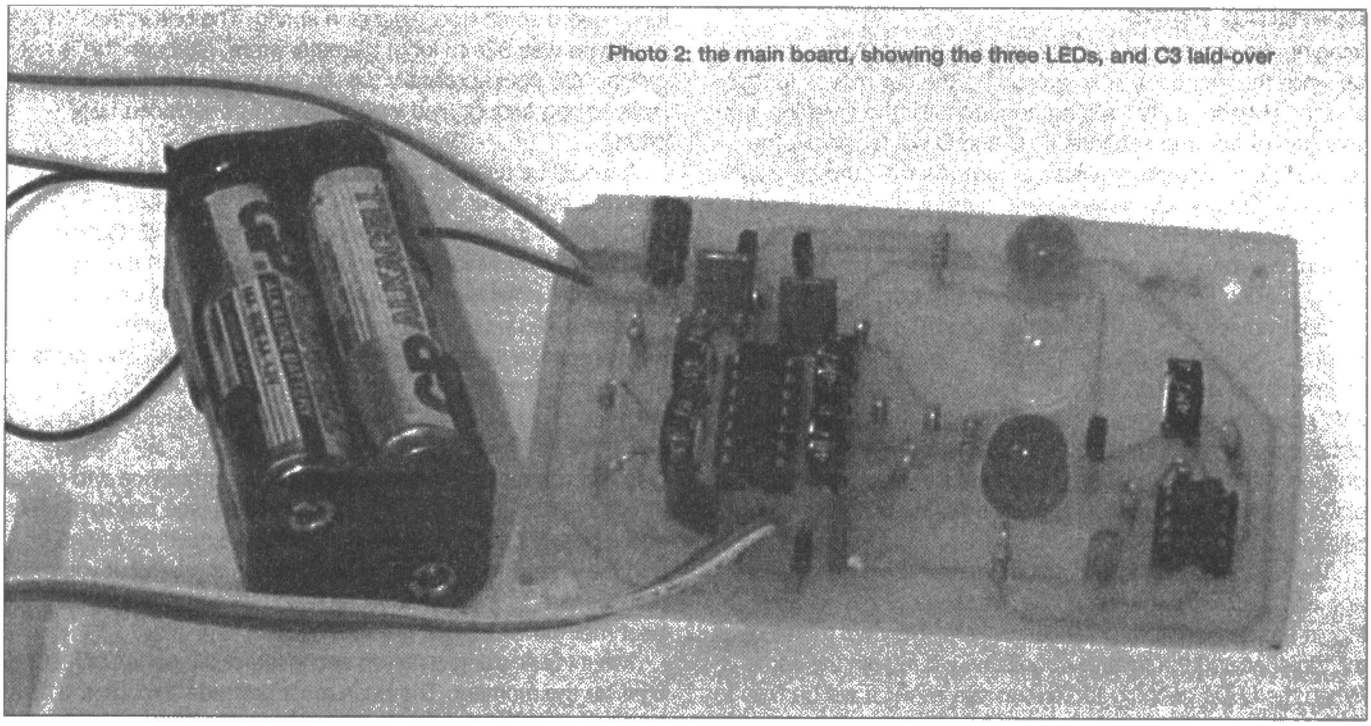


Photo 2: the main board, showing the three LEDs, and C3 laid-over

If the wire has been threaded, use small nuts to secure one end of the spring to the protruding part. If not, drill a 1-mm diameter hole (possibly using a PCB drill) and pass one end through it. Secure the other end of the spring with the bolt in the hole so marked. Check the spring returns the wire correctly when it is released from to its extreme position and that the motion is smooth. Adjust the body of the potentiometer so that the wire moves over the centre part of its track, then tighten the nuts firmly. The unused holes in the sensor assembly will be used to mount it in position later. Solder 20cm pieces of light-duty stranded connecting wire to RV1 tags. Using different colours (say, rainbow ribbon cable) will help to avoid mistakes later.

Main section

With the sensor assembly complete, construct the PCB for the main section. The component layout is shown in **figure 3**. Begin by mounting the five presets RV2 to RV6. A supplier for the 4.7M pots is given at the end, but it would be possible to use 1M (which is more readily available) and 470k for R1 to R8. This would, however, mean an increased standby current requirement. Also, for R20 it would be necessary to substitute a value of 220k and for C2, 47u. Mount the two ic sockets (but not the ics themselves).

Solder the remaining components in position apart from the LEDs. Note the polarity of the transistors, and C2 and C3. C3's leads should first be bent through right angles and soldered so that the body lies flat on the PCB (see the top left of the board in **photo 2**) so that it lies lower than the LEDs. When soldering the LEDs, use minimum heat to avoid heat damage. A simple heat shunt can be used by gripping the wires between the PCB and LED with fine-nose pliers. You can use LEDs are smaller than 10mm, but they would be less easy to see. Solder them so that they stand about 5 mm above the board with their tops level, forming a straight line and equally-spaced. Observe the polarities.

Adjust preset RV2 and RV6 fully clockwise and RV5 fully anti-clockwise. Go to the other end of the board and adjust RV3 and RV4 fully anti-clockwise. This gives a short monostable time-out which is convenient for testing. Solder the battery connector wires to the points labelled +6V (red) and 0V (black). Solder three short different-coloured wires to the points labelled RV1.

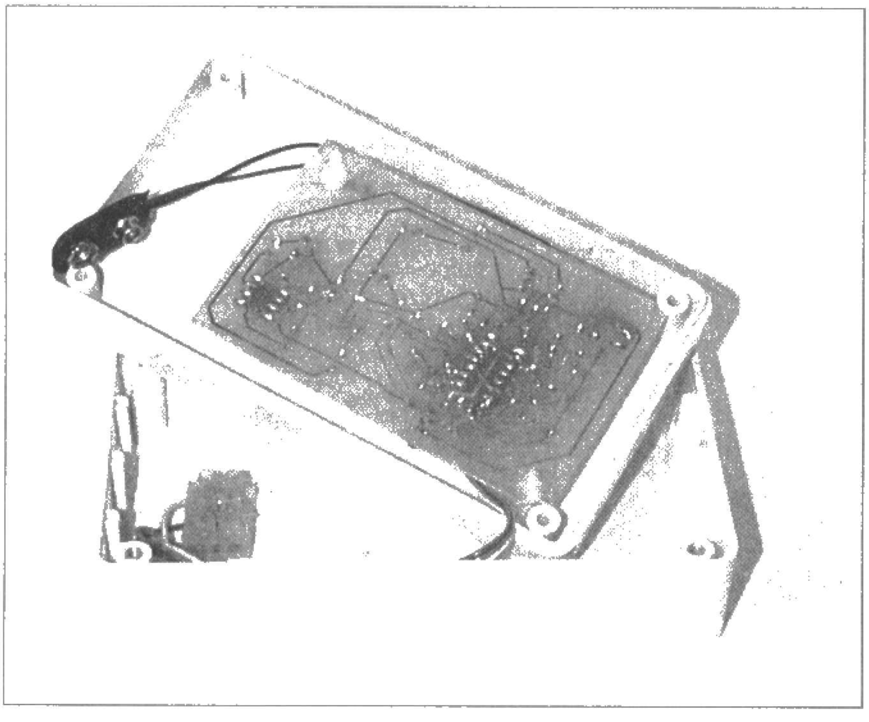


Photo 3: the main board mounted in the lid of its box with the connector block below

Static precautions

Insert the ics in their sockets. These are CMOS devices, so touch something earthed (such as a water tap) to avoid static charge damage before you handle the pins.

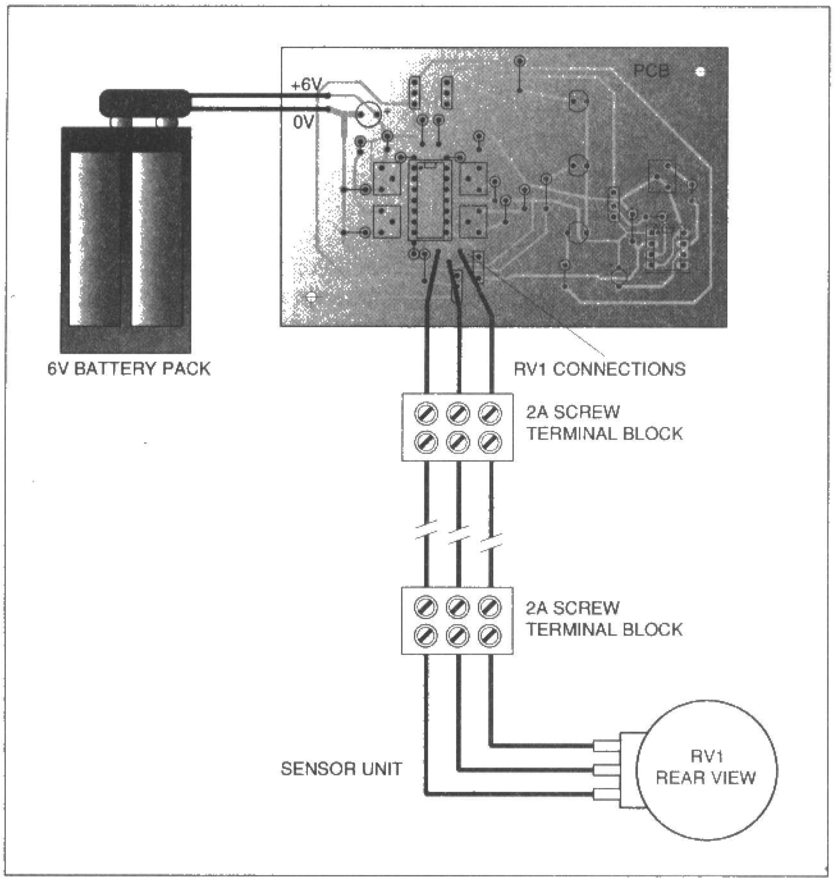


Figure 4: wiring up the main unit to the sensor unit

To prepare main unit box, drill a small hole in the side for the wire connecting it to the sensor, and fixing holes if you are anchoring it to a wall. Measure the positions of the LEDs and drill holes in the lid so that their ends protrude by a few millimetres when the PCB is held in its final position. The PCB will probably be mounted on the lid (see **photo 3**) depending on the box, but do not mount it yet, as you will need access to the presets when setting-up. Fix one of the 3-way pieces of 2A screw terminal block to the bottom of the box and, as shown in figure 4, connect VR1 wires to this.

To prepare the sensor box, hold the sensor in place, measure the position of the slot needed for the wire to protrude correctly (see **photo 4**) and cut it out. It may be possible to remove a small rectangle and use the lid itself as the fourth side (as in the prototype). The exact arrangement will depend on the box. Make a bracket to attach the main unit to the garage wall, and bolt it to the case. If you are going to fix it to the floor or shelves, etc., you may wish to work out another way of securing it, such as strong adhesive tape or pads. Obviously you won't wish to put bolts into anything that may be damaged.

Mount the sensor assembly inside the box (**photo 5**) and check the slot allows unrestricted movement of the wire. Make any adjustments necessary. Attach a plastic sleeve to the tip of the wire or use some padding on it to protect the car. In the prototype, a plastic stand-off insulator was used. Attach a 3-way piece of 2A screw terminal block to the bottom of the box and, referring to **figure 4**, connect RV1 wires to it. For testing purposes, link the two units together using short pieces of wire. Check the terminal blocks are connected correctly as shown.

Setting-up

Note: It will be much easier to adjust the circuit if an assistant is available. Insert the cells in the holder. If the monostable self-triggers the LEDs may come on. If so, wait until they go off. Move the tip of the sensor wire against the spring by about 0.5in (12mm) and adjust RV5 clockwise until the LEDs come on. This is the trigger point of the monostable. Check and re-adjust several times (waiting for the monostable to time out each time) until the setting is correct. Note that due to the positive feedback action referred to earlier, the OFF position will not be quite the same as the ON one. When satisfied with the adjustment, set the monostable time-out to maximum (RV6 fully anti-clockwise). Re-trigger and move the wire a further 1 in (25mm) or so and adjust RV4

Photo 4: the sensor box showing the angle of lean, right-angled upper end (make sure it is pointing the right way when the sensor is threaded into its pot), and plastic buffer on the wire tip

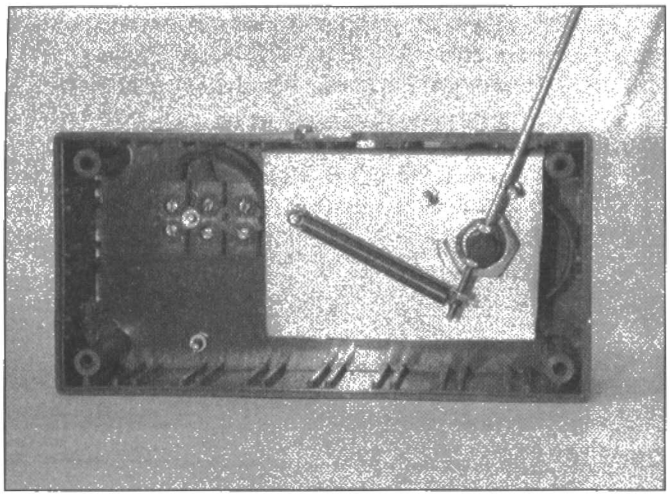


Photo 5: the sensor and spring mounted in its box (lid off)

until the green LED just goes off. Check by moving the wire back so that it goes off again to check the position. When satisfied, go on to RV3 adjustment (for yellow) at about mid-travel and RV2 (for red) near the end. If the monostable times out, relax the wire completely and re-trigger it. If one or more of the correct operating points cannot be obtained, it is likely that the part of your RV1 track being used is too near one end or the other. To correct this, rotate the body slightly in its hole and re-test.

Time how long it takes to park the car in the normal way and adjust RV5 to an appropriate value. Mount the PCB on the lid section of the box (or as appropriate) using plastic stand-off insulators on the bolt shanks if necessary. In the prototype, I found that the presets themselves made good spacers.

Finishing off

Decide exactly how the car will make contact with the sensor wire and fix the unit to the wall or floor (or any other solid object in the right place - but only using sticky pads if it is a piece of household equipment!). Do not bend the wire. Check the box is low enough to avoid being touched by any other part of the car (with highly misleading consequences).

Decide on a suitable place for the display unit and attach it to the wall. Measure a suitable piece of light-duty three-core wire (telephone or burglar alarm type with one of the wires left unused is ideal). The prototype was tested with wire up to 10m (30ft approximately)) long, but it can be longer. Wire up the two units taking care that the terminals in each are connected in the right way round. Put the lids on the boxes, making sure that the LEDs lie evenly in their holes in the main unit (**photo 6**) and test the system thoroughly. If necessary, make further small adjustments to the presets.

Note that no on-off switch is provided. If you regularly leave the garage unused for long periods it would be worthwhile fitting one in the positive battery feed so that it could be switched off to save battery life. The battery pack should give good service until the voltage falls to about 3V. It will be obvious from the brightness of the LEDs when this is happening.

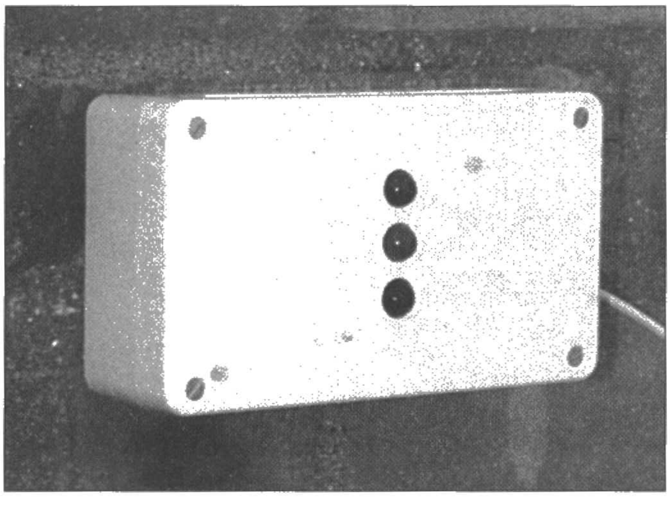


Photo 6: the LED display on the indicator (main) unit

PARTS LIST *for the Easy Parker*

Resistors

R1 to R8	2M2 (see text)
R9, 10, 11	100M (if used; see text)
R12, 13, 14	10k
R15, 16, 17	150R
R18	2k2
R19, 20	1M (see text)
RV1	2M2 standard linear carbon potentiometer
RV2, 3, 4, 5, 6	4M7 vertical miniature presets (see text)

Capacitors

C1	47n metallised polyester- 5mm pin spacing
C2	10u electrolytic (see text)
C3	220u electrolytic

Semiconductors

IC1	TLC27L4ACN quad micropower op-amp
IC2	7555IPA
Q1 to Q4	ZTX300
LED1	10mm green LED
LED2	10mm yellow LED
LED3	10mm red LED

Miscellaneous

Plastic boxes. Materials for sensor - see text. Battery holder and 4 x AA alkaline cells; battery connector; 8-pin dil socket, 14-pin dil socket; 2A screw terminal block: 2 x 3-way pieces.

Most of the components for the Easy Parker circuit are readily available. 4.7M presets for RV2 to RV6 are available from Electromail, PO Box 33, Corby, Northants NN17 9EL. Tel 01536 405555 although 1M components could be used as explained in the text. The 100M resistors, R9 to R11 and the quad-amp are available from the same source. Potentiometer RV1 was ordered from Maplin, PO Box 3, Rayleigh, Essex SS6 8L. Tel 01702 554161.

DIY PCs

Part 2: Major PC upgrades

Robert Penfold investigates the decisions to be taken and processes to be undertaken in upgrading an existing reliable PC to a fully modern multimedia PC. To upgrade or not to upgrade? That is the question.

No doubt most readers have heard the one about the cleaner who used the same broom for 35 years. It only needed 18 new heads and three new handles! The modular construction of modern PCs puts them in much the same category as the cleaner's broom. You can go on adding new components and replacing existing ones indefinitely, producing a so-called 'Peter-Pan' PC. There is a problem with this approach, which is that you will tend to end up with a PC that has all the new features, such as a CD-ROM drive and 3-D sound system, but a relatively slow and old-fashioned processor. You are then faced with the choice of undertaking a major upgrade to bring the PC up to a modern specification, or scrapping it and buying a new one.

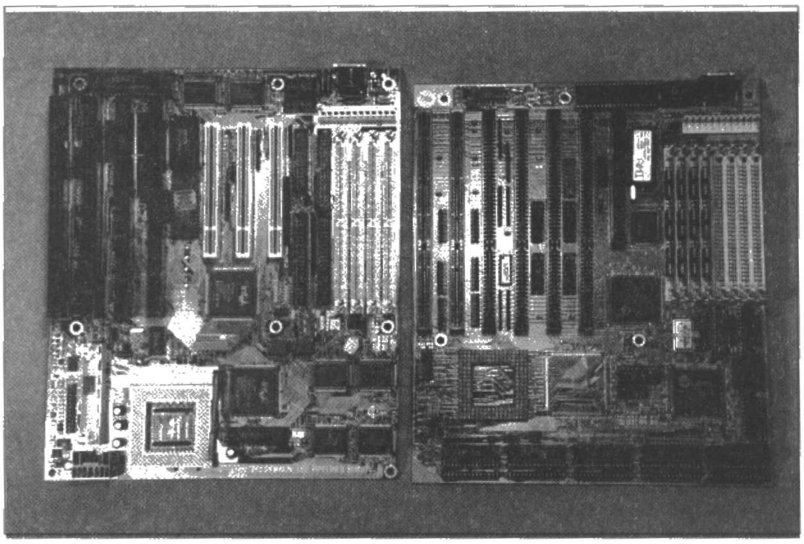
When deciding whether or not to undertake a major upgrade there are two main questions you must ask yourself. The first is whether or not you are up to the task. While it is not something that could be recommended for those who are new to PCs and computing, an upgrade that involves dismantling and rebuilding the PC is not very difficult. As with building a PC from scratch (described last month) it usually requires no more tools than a screwdriver and some basic manual skills. The main difficulty is in selecting the right upgrade components and in getting the refurbished PC up and running properly. Anyone who has at least a few years of experience at dealing with PCs should be able to handle the task without too much difficulty.

It is only fair to repeat the warning given in last month's article: PCs are notorious for obscure problems with incompatibility. The fact that you have good quality components fitted together correctly does not mean that everything will work properly. If problems of this type occur with a ready-made PC it is up to the retailer or manufacturer to sort things out. When building your own PC, or undertaking a major upgrade, you are largely on your own, although the manufacturer of the offending component should be able to offer some assistance. When building and upgrading PCs it is more than a little useful if you happen to own other PCs. With a little juggling of the components, obscure incompatibility problems often disappear.

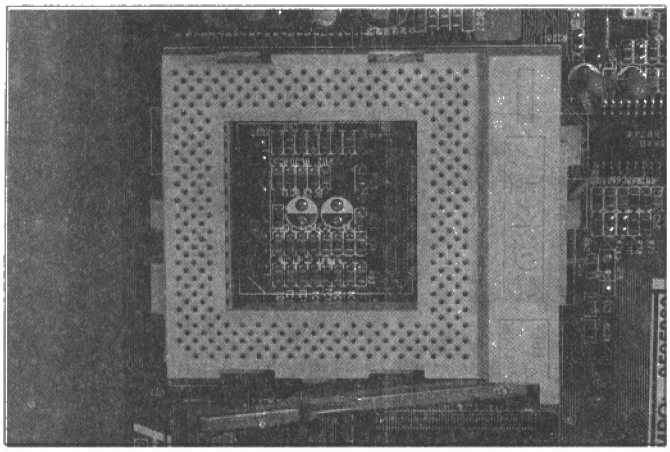
What to upgrade

The second important question is whether your PC is worth upgrading. The 80386 PC I used for work for many years is good example of a PC that is not worth giving the extra time and trouble to. A good computer in itself, it worked reliably for about six or seven years with no replacement components or upgrades. The problem with a PC of this type is that it consists entirely of well-used and out-of-date components that do not form a good basis for a new computer. It would certainly be possible to save some money by using the case and power supply, along with some of the peripheral components such as the keyboard and floppy disk drive if they are in good condition, but this would not produce a great overall cost saving, and might compromise the reliability of the upgraded computer. Unless you are operating on a very tight budget, it would probably be better to build a new PC from scratch.

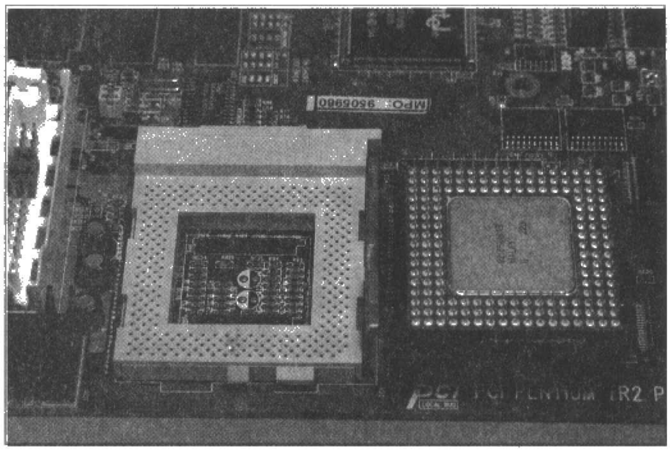
By contrast, the 80386 PC that I used for leisure purposes for many years was a prime candidate for a major upgrade. It had been fitted with a replacement power supply and keyboard, and upgraded with multimedia components and an improved monitor. The processor was too slow to run most modern software, and the total capacity of the hard disk drive was less than the space required by many current software titles! On the other hand, there were plenty of good quality components that could be carried forward into a "new" computer.



The Pentium motherboard (left) and 80486 board (right) are both "baby" AT format boards. They can use the same case and power supply, but require different memory modules



The Socket-7 used for normal Pentium processors is a form of ZIF socket. Note the lever which is used to lock (down) and release (up) the processor

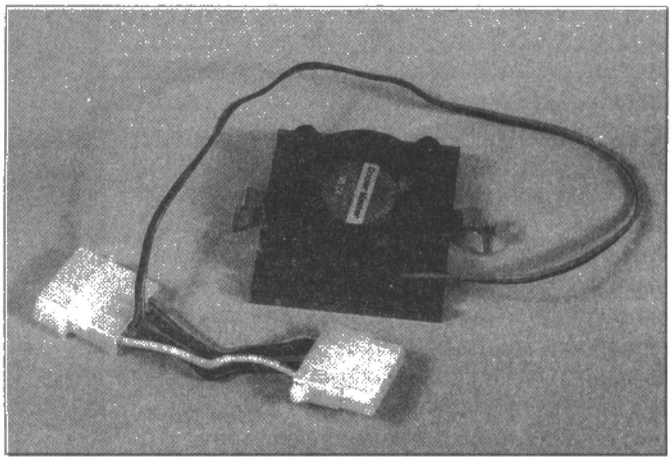


The Socket-7 (left) and 80486 processor (right) may look compatible at first sight, but phycially and electrically they are totally incompatible

When deciding what to upgrade, a good starting point is to look at the specification of a typical new PC. Ask yourself what you would need to change in the existing PC to bring it up to a similar specification. Obviously the processor will have to be changed. The existing computer will presumably be equipped with an 80386 or 80486 processor of some kind, which means that the motherboard will also be incompatible with any form of Pentium processor. Unfortunately, even if the PC is fitted with an early (60- or 66-MHz) Pentium, it will also be incompatible with any of the current Pentium processors. These early processors use Socket-5 motherboards, but more recent versions require a Socket-7 board. In fact, a motherboard may not support modern MMX processors even if the PC has a fairly recent processor such as a 133-MHz Pentium. Apart from the fact that it may not support higher clock rates, most motherboards more than a year or two old can not provide the dual supply voltages required by MMX Pentium processors.

There are actually easy upgrade options for 80486 and older Pentium based PCs in the form of "Overdrive" processors and the like. These can provide a new lease of life for an old PC, but bear in mind that only the speed of processor itself that will be improved. Everything else in the system will still operate at the same speed, which might give less improvement than you were hoping for. Also, fitting a new motherboard is likely to provide the PC with improved facilities such as USB (Universal Serial Bus) ports and a hard disk interface that supports the latest high-speed drives. The extra expense and time involved in a major upgrade is probably worthwhile.

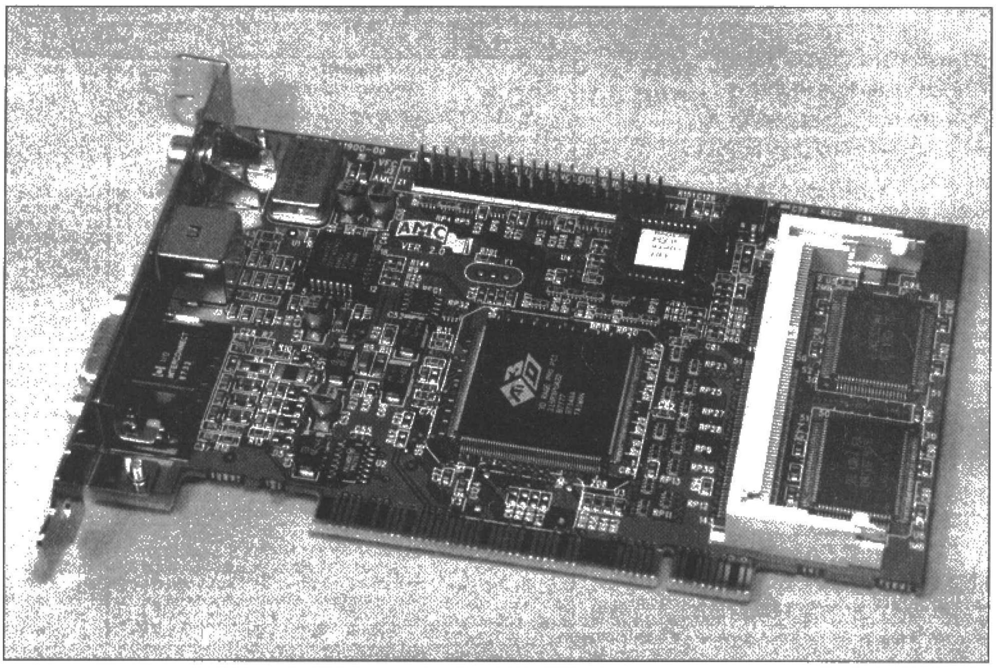
The existing processor may be fitted with a heatsink or a cooling fan, but this will be totally inadequate for any modern Pentium processor. All the current Pentium processors require both a substantial heatsink and a cooling fan. Some processors require more efficient heatsinks and fans than others, so check that you get one that is properly matched to the your new processor. It is best to order the processor and the heatsink/fan at the same time. Any reputable supplier should be able to match up the processor with a suitable cooling system.



A Pentium processor requires a heatsink and cooling fan. This usually taps off power from a disk drive supply lead

- Upgrade your old PC to run 10 times faster for around £200
- USB is supported by Windows 98, which should be out when this appears
- Early implementations of AGP showed no real advantage over PCI for video cards, but some of the best new video cards are now only available in AGP format.
- Beware cheap Pentium II motherboards - they may not support the faster grades of Pentium II processor.
- Intel's fastest Socket-7 processor runs at 233 MHz, but other manufacturers such as Cyrix and AMD make faster Socket-7 devices.
- Non-Intel processors can deliver higher performance for lower cost, but rumours are flying round the Internet that the dreaded "blue screen of death" (shut down and reboot) appears more often in badly-behaved software when using these processors, due to the way that they optimise their code.
- Email us on eti@aaelectron.co.uk to tell us whether you want more about PC hardware

ERROR ERROR Reality.sys fragmented. Reboot universe (y/n)?



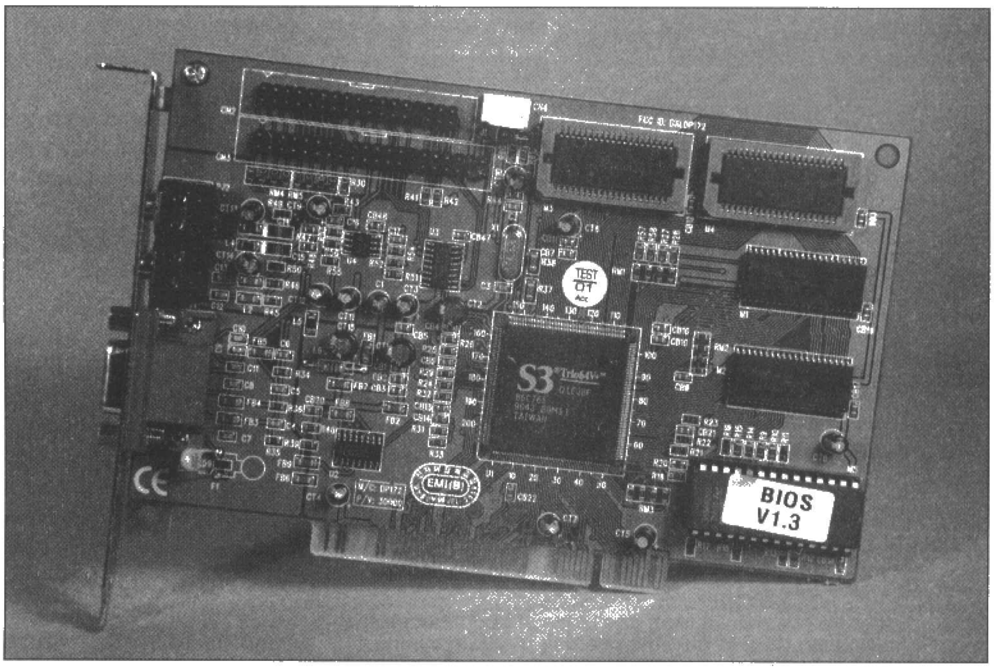
If you are heavily into graphics applications, a good 2D/3D card such as this ATI Expert at Play board is a good investment

While a new processor, heatsink/fan, and motherboard may be all that you need, it is likely that you will also need a new memory and/or a new video card. If the existing motherboard uses 30-pin memory modules, it will not be possible to use these with a new motherboard. It is actually possible to obtain adapters that permit 30-pin memory modules to be used with 72-pin sockets, but with the current low cost of memory these are not a very worthwhile proposition. Even if the existing memory is of the 72-pin variety, it may not be compatible with your choice of new motherboard. Pentium II motherboards require 168-pin SDRAM memory modules, and it is probably worthwhile using these with ordinary MMX Pentium class processors as well due to their higher speed. Most non-Pentium II motherboards will accept 72-pin EDO ram modules, and these represent a good low-cost alternative to SDRAM modules. The saving in cost is becoming smaller, though, and EDO ram will soon be obsolete. If you use a high-speed motherboard that operates at 100MHz, make sure that you use SRAM modules that are fully compatible with the board. Some SDRAM modules are rated at 100MHz (10ns), but are not guaranteed to be compatible with the latest motherboards.

If the computer you are upgrading is one of the later 80486 machines it might be fitted with a video card that fits into a PCI expansion slot. It is more likely that the video card will be an ordinary ISA type, or possibly a VESA card. It is possible that an ISA video adapter could be used in a modern Pentium computer, but it would severely hamper the graphics performance, particularly in any Windows applications, and could not be recommended. The VESA expansion bus is now obsolete, and there is no chance of using an old VESA video adapter in a modern computer.

Good video cards are no longer very expensive. A video board based on one of the popular S3 graphics chips, with 2 MB of memory, only costs about £20-30 sterling. Although this will not quite provide "state of the art" performance, it should be more than adequate for most purposes, and will easily outperform most video adapters that are more than about four years old. If you are heavily into graphics applications you will probably be a lot happier with one of the faster 2D/3-D video cards which use the new AGP (advanced graphics performance) interface. In general, you get more performance for your money using a moderate processor and a fast video card than using an up-market processor and a run-of-the-mill video board.

Buying a new Pentium processor, motherboard, video card, heatsink/fan, and about 32 MB of modern ram will not be cheap. On the other hand, with the current 'giveaway' prices it may cost less than you think. If you opt for an up-market processor, it will be expensive, because the processor alone will set you back several hundred pounds, so, unless you really must have the ultimate in performance, opt for a more modest processor such as a 233-MHz MMX Pentium type. This will provide you with a PC that will happily run any current software, and will literally be ten times faster than your original PC. The cost is likely to be around £200, but this is quite modest when compared with the improvement in performance.



An inexpensive video card based on one of the S3 chips will provide quite good performance

Slipped disk

Many 80386 and 80486 PCs are fitted with hard disk drives of a capacity of about 250 MB or less. These were fine in the days of MS-DOS and Windows 3.X, but are not adequate for a computer running Windows 95 or beyond. If you are upgrading a PC that still has its original hard disk and you wish to bring it up to a standard that will run modern software, upgrading the hard disk will probably be essential. Fortunately, like nearly everything else in the computer world, hard disk drives now offer much more for much less. A 3- or 4-GB hard disk drive need cost no more than about £100. This is more than enough for any normal purpose. Modern hard disk drives and motherboards support the high-speed UDMA33 interface. Added to general improvements in performance over the years, this will result in a massive improvement in performance compared with your existing drive.

Compatibility

Last month's article explained the difference between AT and ATX motherboards. When upgrading you will normally have no option, and will have to use an ordinary AT form factor board, as this is only type that will fit into the existing case. However, some PCs have non-standard cases and motherboards, and a major upgrade to one of these is probably not possible. It is mainly the larger manufacturers that do their own thing, and use motherboards of non-standard sizes with the fixing holes in all the wrong places. Modern 'clones' use motherboards based on the original AT design, but they are invariably cut down versions, or so-called 'baby AT' boards. If your PC has a standard motherboard it should be something like the one outlined in **figure 1**. Bear in mind that the exact size will vary from one board to another, and that some of the mounting holes may be absent.

Although at one time there were no AT-type Pentium II motherboards, there are now several to choose from. A potential problem with these is that the large size of the processor module (particularly its height) could make it difficult, or even impossible, to fit everything into the case. Also, there could be a problem finding unobscured expansion slots that will take longer cards. There will probably be no problem if your case is one of the larger types, but it is probably not worth trying if the computer is in a slim-line or mini-tower case.

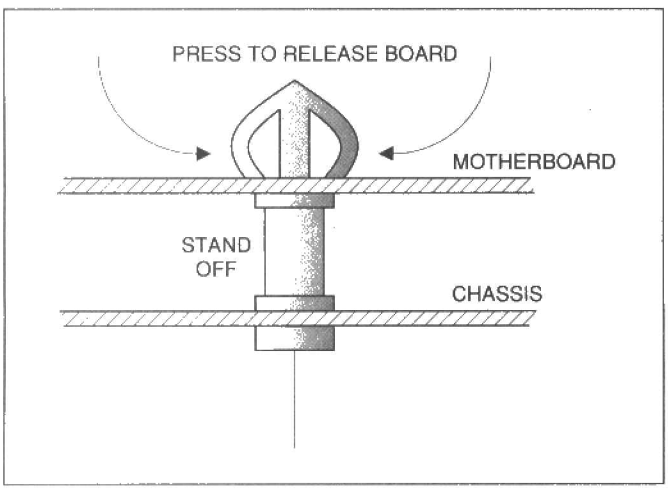


Figure 2: there is normally at least one mounting bolt, but plastic stand-offs are also used to hold the board in place. In theory at any rate, you just squeeze the top of the stand-off and pull the board carefully clear

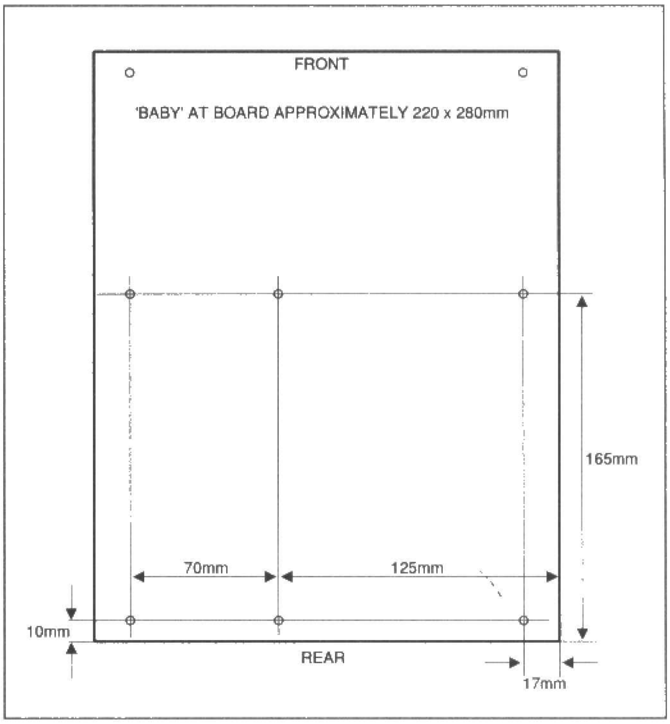


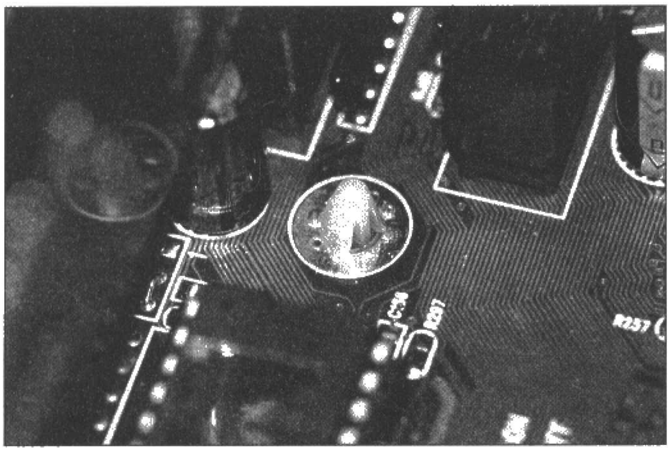
Figure 1: the positioning of the six main mounting holes in a "Baby" AT board. Real-world boards often have only five of these

Using a Pentium MMX class processor and a Socket-7 motherboard is a cheaper and safer option. Whatever processor you use, it is **essential** to carefully choose a fully compatible motherboard. The new 350- and 400-MHz Pentium II processors require the latest "BX" chipset Pentium II motherboards. These support a 100-MHz system clock rate and the new fast SDRAM modules. Be wary of cheap Pentium II motherboards, as most of these do not support anything beyond 300-MHz or even 266-MHz Pentium II chips. They are fine if you only wish to use one of the slower Pentium II chips, but they do not offer any scope for fitting a faster processor when the prices drop to more affordable levels.

Although Intel does not manufacture normal Pentium chips for operation beyond 233-MHz, other manufacturers have come up with 266-MHz and even 300-MHz Socket-7 chips. The non-Intel chips often have different supply voltage and/or clock requirements to the Intel articles. The motherboard manufacturers make their products as versatile as possible and any reasonably up-to- date board should be able to accommodate a wide range of processor types and speeds. It is still important to check that the board you want to use actually supports your choice of processor. This is especially important if you are going to use one of the new super-fast Socket-7 processors. Only the very latest motherboards have support for these. It is also very important if you opt for an IBM/Cyrix M2 chip, as these mostly require high system clock frequencies that are not supported by many motherboards.

Dismantling

Once you have assembled all the components for the upgrade, the first task is to remove the existing motherboard complete with the processor and memory modules. PCs are not particularly small, so find a reasonably large working area and use some old newspapers to protect the worktop. Depending on your case, once the outer cover is removed you may have easy access to the motherboard or it may be virtually buried out of sight. Either way, all the expansion cards must be completely removed from the computer and



Plastic standoffs are often used to hold motherboards in place. Unfortunately, they usually exhibit the bulldog spirit when it comes to being removed. You may need an assistant. It is very important not to flex a motherboard or other circuit board that you wish to use a second time ...

any leads that connect to the cards or motherboard must be disconnected. If possible, only disconnect the ends of the cables that connect to the motherboard or expansion cards. If you do find it necessary to disconnect cables from the disk drives, etc., make some simple but careful sketches that will enable you to reconnect the cables the right way round.

If you are lucky, removing about half a dozen or so screws will enable the motherboard to be lifted clear of the case. Alternatively, it may be a matter of removing one or two screws and then sliding the board slightly to one side so that it can be removed from the case. The board will still be attached to some plastic stand-offs, and these must be carefully removed so that they can be used on the new motherboard. This is generally just a matter of squeezing the tops of the stand-offs using pliers and then pulling them free from below (**figure 2**). If you are unlucky, having removed one or two screws the board and plastic stand-offs will not slide free from the case. It may be possible to free the stand-offs from the case if you have access to the underside of the base panel.

However, the construction of some cases is such that you will have to use pliers to free the board from the stand-offs one-by-one. This tends to be very tricky because one stand-off will do its best to slip back into place while you are removing the next one. You will probably need a helper to prevent this, or will have to improvise some wedges to prevent the board from slipping back onto the stand-offs.

The new motherboard and processor are both static-sensitive and require the same handling precautions that would be used when building a project with MOS devices. Some form of earthed worktop is required, but this can simply provided by a large sheet of aluminium foil connected to (say) the earth terminal of a bench power supply unit. Touch the foil from time to time to remove any static charges that build up in your body. Where required, any configuration jumpers or DIP switches should be given the appropriate settings before the motherboard is fitted into the case. It is also advisable to fit the memory modules and the processor while there is easy access to the motherboard. This was all covered in last month's article and so I will not go over it in detail again here.

Fitting the new motherboard in the case is just a matter of reversing the process used to remove the original. There are a couple of potential minor problems. The mounting holes in the original board might not completely match up with those in the new board. The case will probably have provision for more mounting points than any one motherboard actually uses. The mounting holes that are omitted vary from one board to another. It is unlikely that there will be any mounting holes in the motherboard that do not have any matching mounting points on the case, but it is advisable to compare the two before you actually start fitting. Provided at least five or six holes in the board have corresponding mounting points on the case, the board should be adequately fixed in place.

The other problem is that the new motherboard is sometimes slightly larger than the original. The case should still be able to accommodate the new motherboard quite happily, but it might be necessary to temporarily remove the power supply unit or some of the disk drives in order to provide access for the motherboard. **Do not try flexing the board** in order to manoeuvre it into place, as this is very likely to damage it.

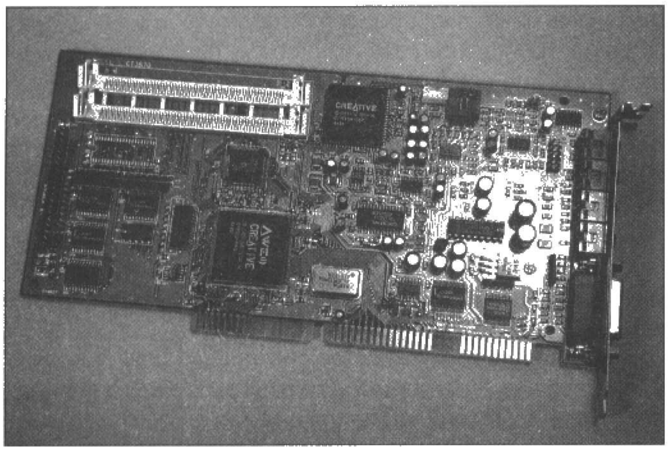
The right connections

With the motherboard in position, then comes the matter of re-connecting all the cables. Things change over the years, and this will probably enforce some changes in the cabling. Modern motherboards include all the standard interfaces on-board, whereas the original computer probably relied on expansion cards to provide all or most of them. Expansion cards, which only provide facilities that are available on the motherboard, should therefore be omitted from the upgraded computer. The CD-rom drive probably connected to an IDE interface on the sound card in the original computer. Obviously the sound card is still be needed, but the IDE interface is not and where possible it should be disabled.

The motherboard will have two IDE connectors, each of which supports two devices. At least a basic set of cables should be provided with the motherboard, and this will include an IDE lead that can be used to connect the primary IDE interface to both the hard disk and the CD-rom drive. This method will work quite well, but data transfers from the CD-rom drive to the hard disk might be faster if they use separate IDE interfaces. Using the cable supplied with the motherboard and the one from the original computer there should be no problem in connecting the hard disk drive to the primary IDE interface and the CD-rom drive to the secondary interface. Internal data cables are usually made from grey ribbon cable, and the convention is for the red lead to carry the pin one connection. The motherboard's manual should have a diagram that indicates the position of pin 1 for each of the on-board interfaces. The motherboard itself will probably be marked with this information as well.

If the hard disk has been upgraded, you may wish to retain the old hard drive, even if only temporarily to make it easy to copy files from the old drive to the new one. In order to do this the CD-rom drive must be connected to the secondary IDE interface, leaving the primary interface free for the two hard drives. The twin IDE lead supplied with the motherboard can be used to make the connections to both drives.

If you have more drives than power supply connectors, a supply splitter lead will be needed to enable two drives to be powered from a single supply output. Configuration jumpers on IDE devices set them as either master or slave devices, or in the case of a hard drive it may also be configurable as the only device on that particular IDE interface. Refer to the manuals for



The Soundblaster 32 is no longer the last word in sound-cards, but it is the type of component that is worth retaining when upgrading

your drives, and make sure that all the IDE devices are configured correctly. The boot drive is the master device on the primary IDE interface, which will presumably be the new hard drive with the old drive acting as its slave.

The cables supplied with the motherboard should include a set for the twin serial ports and single parallel port. The 25- and 9-way D connectors will be mounted on blanking plates that fit on the rear of the computer in the spaces formerly occupied by the serial and parallel port cards. Most of the current motherboards have a PS/2-style mouse port, and a connector for this will probably be included with one of the serial/parallel blanking plates. If you are using a serial mouse it is still worth connecting the mouse port in case it is required in the future. It is virtually certain the motherboard will also be fitted with a USB (universal serial bus) interface, but it does not seem to be normal practice to include a lead and blanking plate for this. This accessory is normally available, as an optional extra, but there is probably no point in obtaining one unless you actually intend to use the USB port. It seems likely that the USB ports will be used a great deal in the future, but difficulties in getting them to work properly under Windows 95 means that there is little support for them at present. The USB seems to be virtually "on hold" until Windows '98 arrives.

There are connectors for minor functions on the motherboard, such as the reset and "turbo" switches and the loudspeaker. You are more likely to win the lottery than to find that the minor facilities on the motherboard match up with those of the case. For example, modern PCs do not normally have any form of "turbo" facility (they always run flat out), which will render the "turbo" LED and switch unnecessary. It may be possible to use the "turbo" LED for another purpose, such as an over-temperature indicator, but in general it is just a matter of connecting those facilities that are common to both the motherboard and the case and ignoring the rest.

Testing time

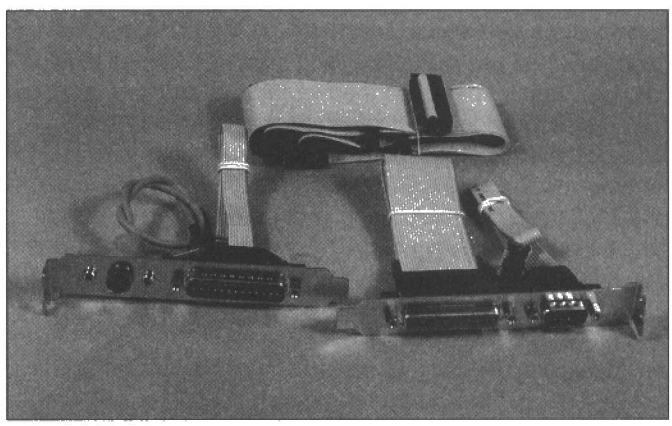
Once everything has been put back together and the base unit has been re-connected to the monitor, give everything a final check before switching on and testing the "new" computer. After switch-on there should be some BIOS messages. These will obviously be slightly different to those that used to appear, because the BIOS and general configuration of computer have been changed. If the computer is still fitted with the original hard disk drive it should boot up more or less normally if you are running MS-DOS. If you then go into Windows 3.X it is unlikely that it will work properly if the video card has been a changed, or even if the amount of memory fitted has been altered. The Windows Setup program is used to install the drivers for the new video card, and to carry out any other changes in the Windows configuration.

If you are running Windows 95, the new video card should be detected by the "plug and play" facility. It is then just a matter of following the on-screen messages, plus any directions given the in the video adapter's manual. It is worth checking for any "Readme" files on the installation disks or CD-rom to see if there are any last-minute changes to the procedure. The Windows 95 "plug and play" feature does not always perform as it should, and if there are any problems in installing the new video card it may be necessary to start the computer in "safe mode". To enter "safe mode", press F8 as soon as the "Starting Windows 95" message appears, and then choose "safe mode" (option three) from the menu. It is then a matter of going to the Windows control panel, running the "add new hardware" option, and following the on-screen prompts to install the video card. You can try the automatic hardware detection facility, but it is probably better to opt for manual installation. Select "video adapters" from the list of hardware types, and then use the "have disk" option to install the drivers from the disk or CD-rom provided with the video adapter.

Although one might expect that the change of motherboard would be of no consequence to the operating system, Windows 95 will almost certainly detect that the board is based on a different chipset. It will then try to load new drivers to support the features of the new motherboard. It is advisable to have the Windows 95 CD-rom handy, as this may be needed in order to load some of the drivers. In my experience, modern motherboards may well cause Windows 95 to reboot and load additional drivers two or three times before you finally get the operating system booted-up. Consult the motherboard's manual for advice about operation under Windows 95. Some features of the motherboard may be too modern for Windows 95 to handle properly, and it may be necessary to use software provided with the board to straighten things out.

If you have upgraded the hard disk, you are effectively dealing with a new computer and must set it up "from scratch" (as described in last month's article).

In next month's concluding article we will take a detailed look at dealing with the BIOS, hard disks and UDMA33 support, and what to do if you new or improved computer has a mind of its own.



The serial, parallel and mouse port connectors are installed in place of the original controller cards. The main interfaces are provided by the motherboard

High Quality 100W Mosfet Power Amplifier

In the second and final part of this project, David N J White describes suitable power supply circuits, loudspeaker protection and testing of the unit.

In last month's issue, I described the principles on which I designed the mosfet amplifier, and printed the circuits, component layouts and Parts List. We will finish the construction in this part, and the price and source for the PCBs will be given at the end.

Power supplies

The power amplifier needs a +/-50 V power supply. Suitable circuits were shown in Part 1 last month in **figures 6a and b** for powering a single or a pair of power amplifiers respectively. For a single power amplifier (**figure 6a**) the (preferably toroidal) transformer should be rated for at least 160 VA (225 VA preferred), while a pair powered from one transformer requires a minimum rating of 300 VA (500 VA preferred). The smaller transformers will supply enough current to give around 100 W/8-ohm and 130 W/4-ohm output from the power amplifiers, while the larger ones will supply enough current for 100 W/8 ohms and 160 W/4 ohms . The colours of the transformer leads shown in **figure 6** correspond to those supplied by Maplin - they may be different for transformers from other suppliers. Toroidal transformers from other suppliers or manufacturers, such as Airlink, Antrim, Farnell, ILP, and RS, with 35 - 42 V secondaries are also suitable.

The mains input filters are not strictly necessary, but they cut down the likelihood of switching and/or motor interference from heavy domestic appliances. I personally prefer to use IEC mains inlets which integrate the mains connector, fuse, switch, and filter in one housing; this cuts down on the amount of exposed mains wiring.

Ideally each power amplifier of a stereo pair should have its own independent power supply, but this is expensive. A single transformer serving separate rectifiers and capacitor banks for each power amplifier is a good cost-effective compromise. Be prepared for the fact that the power supply will cost more than the power amplifier itself, although it is often possible to pick up suitable transformers cheaply by scanning the surplus advertisements in ETI and other electronics magazines.

It is better to use three smaller electrolytic capacitors, rather than one big one, to smooth each of the positive and negative supply lines, as shown in **figure 6**. These capacitors will account for a significant part of the total cost of a power amp/psu combination, and it is possible to save money by using 3300uF parts while still getting perfectly satisfactory performance. Equally, using larger or better quality components will reduce ripple on the power supply lines and lead to better handling of bass transients, albeit at higher cost.

The power supply can be either hardwired, constructed on stripboard, or constructed on single-sided glass fibre copper clad board. I recommend the latter option; simply drill the board to take the rectifier bridge, snap in capacitors, fuses and spade connectors and then cut the copper with a scalpel or burr to make the circuit. Don't use a scalpel with a snap-in blade - the blades fly out easily when you are cutting. If you must use a scalpel, use one where the blade is retained by a screw-up clamp. The power supply circuitry is so simple that it is not worth etching a pcb, but for those of you who prefer a ready-made pcb the Maplin High Quality PSU pcb (order code GE29G) is suitable. The complete kit based on this pcb is expensive because it uses very high quality electrolytic capacitors for smoothing. The price can be reduced by a factor of three if you buy the pcb only and then use more ordinary 10,000 uF smoothing electrolytics; any difference in sound

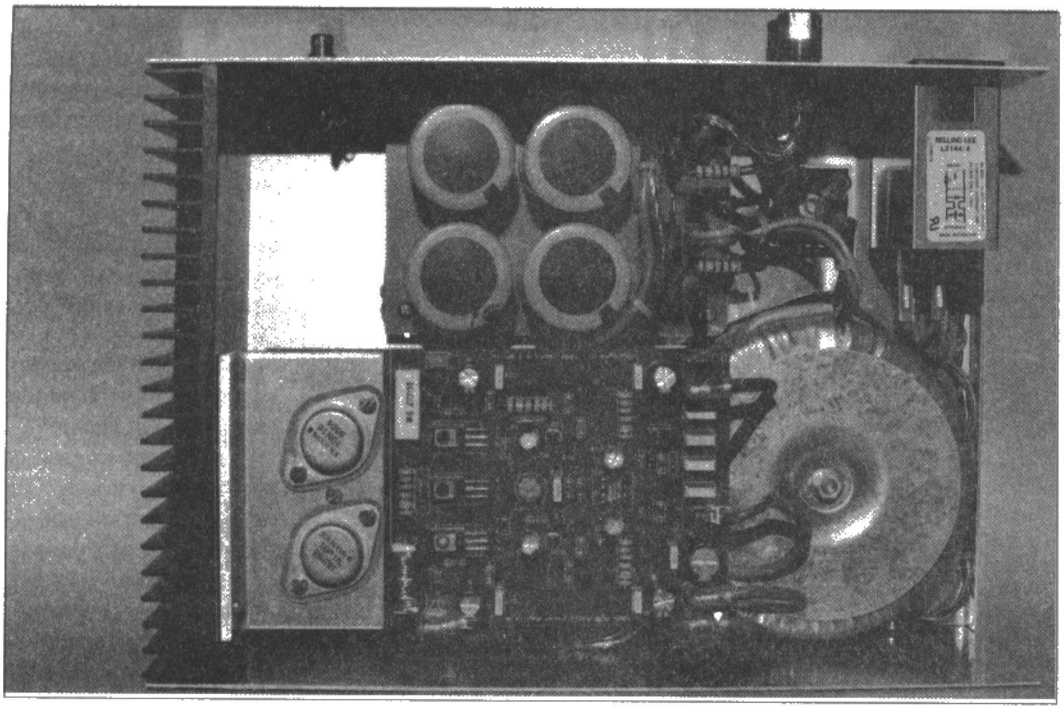


Photo 2: a cased mono power amplifier showing power supply and heatsink.

quality is likely to be detectable only by the "golden-eared". You don't need to populate the +/-15V or +/-17V auxiliary power supplies with components either. If you want a power on/off indicator I recommend a led in series with a 10k, 2W resistor connected between the +50V and -50V power lines of any of the power supply options.

The power amplifier should be connected to the power supply and input/output sockets as shown in **figure 7** for a mono system. For a dual mono system repeat everything from the mains inlet/filter/switch/fuses onwards; for a stereo system using a **figure 6b**-style power supply and repeat everything from the power supply onwards. It is particularly important that the single-point star earthing scheme is adhered to and that the input phono socket is insulated from the (metal) case. **Use only one of the 0V connections on the power amplifier pcb**; it doesn't matter which, but the one which gives the shortest distance to the psu star earth in your particular layout is safest. If you use both connections you will create an earth loop, leading to possible problems with mains hum. **The protective earth connection to the metal case MUST be made, or the case could become live in the event of a fault or wiring error. It makes good sense from a safety standpoint to make sure that the mains inlet, preferably an IEC filtered type, is covered by a protective rubber "boot" and that any connections to the mains switch and mains fuse are impossible to touch and properly insulated**. Using rocker switches and fuseholders with "Faston"/"Lucar" spade connectors makes good insulation straightforward if you use the soft plastic covers for the spade receptacles. **However, the protective earth connection should be soldered to the IEC mains inlet terminal, and connected to the metal case using a bolt not used for any other purpose**. This avoids the possibility that the connection will be inadvertently omitted after dismantling for a repair or upgrade. **This part of the project involves mains voltages: get a more experienced constructor to handle this part of the project for you if you are not experienced and comforatable working with mains voltages. Photograph 2** shows a completed mono power amplifier, built around a manufactured pcb, and power supply.

MODMODMOD

In the 100W MOSFET Amplifier (Issue 7, 1998) in figure 4, the circuit diagram, R11 2k2 should be shown between the base and emitter of Q2 (just below RV1 on the diagram). In figure 5, the component layout, the label +V at bottom left should read 0V. However, the same 0V track is correctly labelled at top left (and on figure 7 in this issue, below). ZD3 (top right) is shown in the wrong orientation: the cathode should go to +V. The amplified diode on page 48 is Q7. Please write to Jenny Etheridge at Nexus House if you would like corrected copies of these two diagrams.
In the Parts List, C14 should be 100pf (BX28F) and the 47p BX26D is C15. The 100u capacitors C9,C10,C11 and C12 should be 25V, Maplin no. AT48C. These are shown correctly in figures 4 and 5.

Loudspeaker protection

Although the protective zener diodes and fuses will protect loudspeakers attached to the power amplifiers from most things, a large sustained DC offset at the power amp output caused by component failure could wreck your loudspeakers. This eventuality is mercifully remote. I have not experienced it in twenty years of fiddling with amplifiers and loudspeakers, but it can happen. For added peace of mind, and particularly if your loudspeakers are expensive, add circuitry to protect against DC offsets.

I considered designing protection circuitry into the power amplifiers, but this would make the pcbs more expensive for those who don't want this facility. Excellent stand-alone protection devices are available at low cost. I use the Vellman K4700 Loudspeaker protection kit, available from Maplin (order code VE24B) and other suppliers. The K4700 is very small and can easily be fitted inside the power amp enclosure. It protects a stereo pair of power amplifiers by disconnecting the loudspeakers via a relay when more than +/-1V DC is detected on the output. It also eliminates switching "thumps" in the loudspeakers. The anti-thump circuitry doesn't serve much purpose with my power amplifier, as the soft start and decay of the led-driven constant current sources, and the very low output offset voltage, give the barest "plop" on switching on and off.

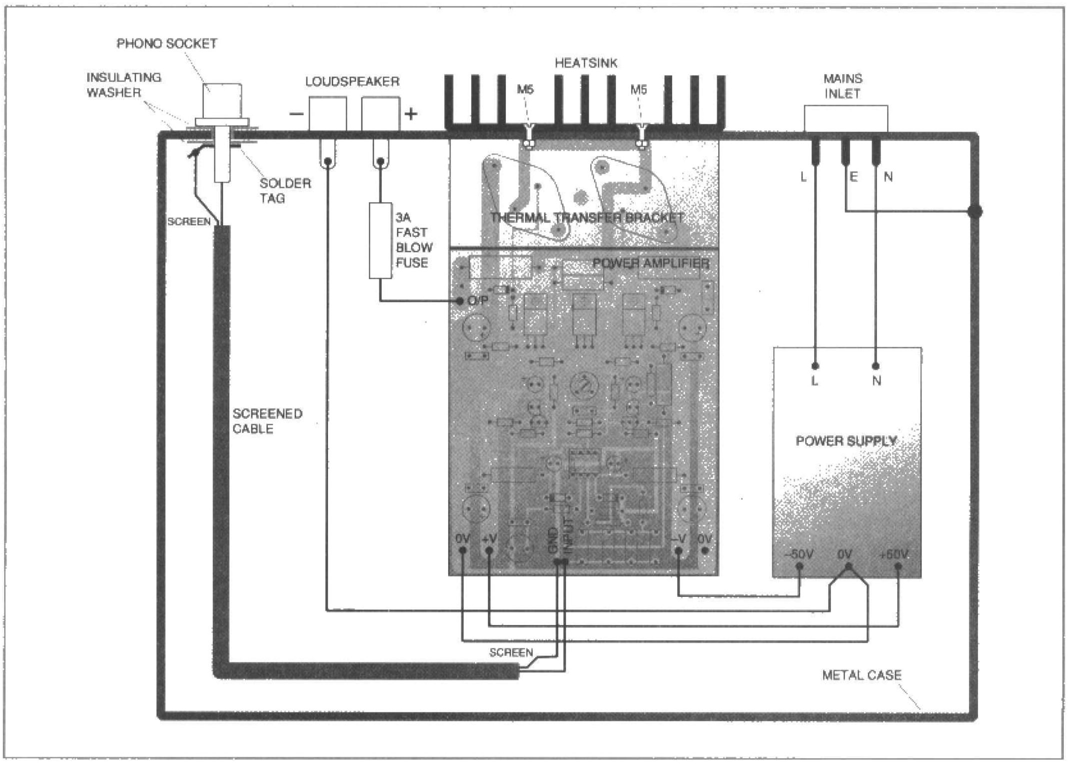


Figure 7: the power amplifier and psu wiring

Testing

If you have made your own pcb, now is a good time to check component values and locations and look for dry joints and unintended solder bridges between adjacent tracks. Also check that there are no cracks or breaks in the tracks due to faulty resist or slight over-etching. If you constructed the power amplifier on stripboard, apply similar checks. If you are using the manufactured pcbs the only likely error is inserting resistors in the wrong position. I misread a resistor value when building a stripboard prototype, resulting in 35V on the gates of the power mosfets at power up! The fuses blew. The datasheet quotes an absolute maximum of +/-14V on the gates, so I resigned myself to £10-worth of blown mosfets. Amazingly, both survived. Either Exicon's figures are extremely conservative or they make very tough mosfets (or both), but I wouldn't bank on being so lucky a second time.

Before commencing setup/testing, make sure that RV1 is turned fully anticlockwise and that the power supply is turned off. Temporarily replace the power supply output fuses by 500 mA fuses and connect the power amplifier to the power supply via an ammeter capable of reading at least 2A in the positive supply line. Switch on the power supply while watching the fuses. If the fuses blow or the meter reads more than 0.1A, turn off the power at once.

Blown fuses indicate a construction error of some kind; disconnect the unit and check all of your power supply wiring. Recheck your board of whatever kind very carefully. A high current reading, assuming that RV1 really is turned fully anticlockwise, means that the amplifier is oscillating (my prototype drew about 0.4A when oscillating). Oscillation is nearly always caused by overlong (longer than 300 mm) power supply connections to the power amplifier, or overlong connections between the stripboard/pcb and separately heatsinked power mosfets.

If all is well, gradually rotate RV1 until the quiescent current is around 100 mA. Leave the power amplifier turned on for about 10-15 min, during which time the quiescent current will rise to maybe 130 mA and fall back again. Make a final adjustment of RV1 to set the quiescent current to 100 mA. You'll find that setting the quiescent current requires a delicate touch on RV1. **Turn off the power, replace the 500mA fuses with 3A fuses**, and the power amplifier is ready for use.

Performance

The square wave performance of the power amplifier at 10 kHz is shown in **photographs 3a - 3g**. Testing at lower frequencies represents a much less severe test, so these results are not given here. For all of these tests the input filter was disabled by removing C4.

The input signal, **photograph 3a**, may be used for reference to illustrate the very slight hf rolloff with purely resistive 4- and 8-ohm loads shown in **photographs 3b and 3c** respectively; the addition of 0.1uF in parallel with the load resistor "squares up" the 4-ohm response, but causes a very small overshoot in the 8-ohm response as shown in **photographs 3d and 3e** respectively. With a heavily capacitative load of 1.0uF in parallel with 4 ohms, the output shows a small amount of well controlled ringing as seen in **photograph 3f**, while with 1.0uF in parallel with 8 ohms the ringing is more marked, but still under control, as can be seen in **photograph 3g**.

These photographs show that the power amplifier is unconditionally stable, in contrast to some well regarded commercial power amplifier modules that I subjected to the same regime. The remainder of the performance is summarised in the table below (IC1 = OPA604, 160 VA toroidal transformer,

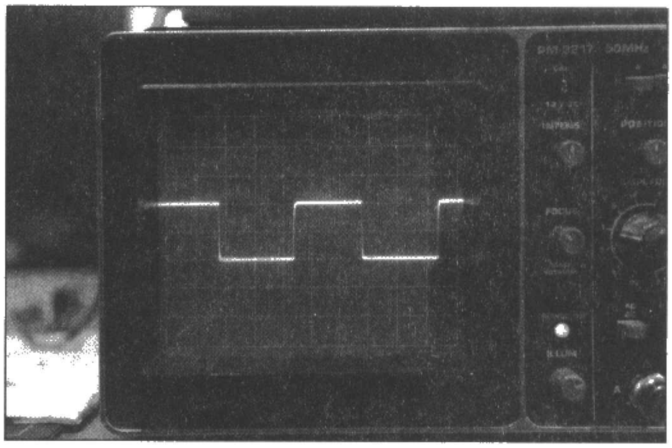


Photo 3a: the 10 kHz input to the power amplifier (1V/cm).

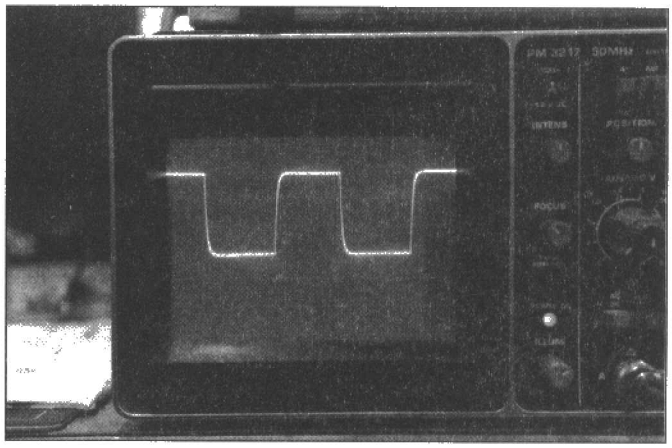


Photo 3b: the power amplifier output into a 4-ohm load (5V/cm)

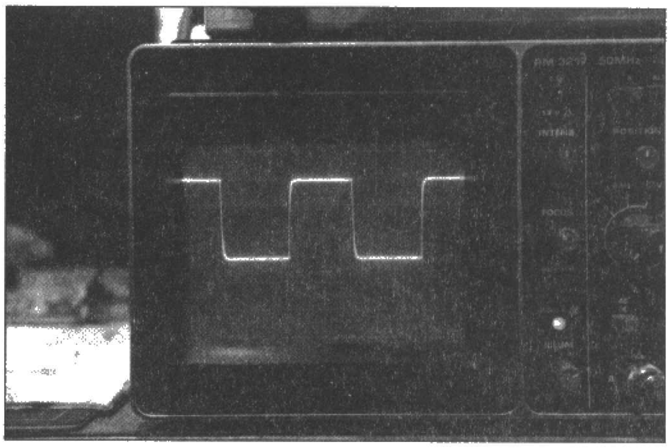


Photo 3c: the power amplifier output into an 8-ohm load (5V/cm).

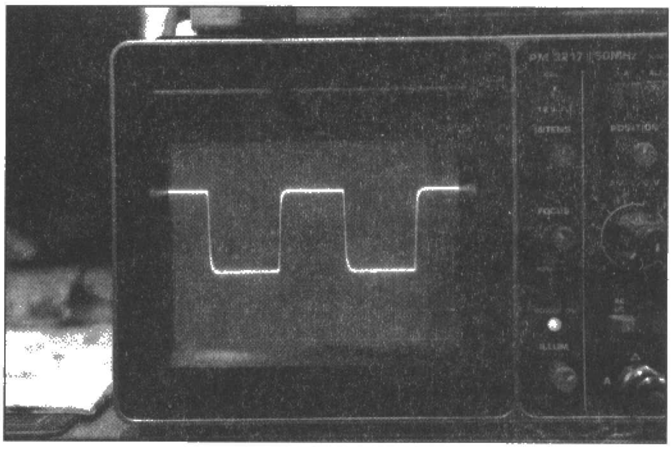


Photo 3d: the power amplifier output into a 4-ohm in parallel with a 0.1uF load (5V/cm)

C4 removed).

Input sensitivity	1.23V rms (full output into 8 ohms)	
Input impedance	47 kilohms	
Output power (continuous)	100 W rms into 8 ohms (1 kHz sinewave)	
	130W rms into 4 ohms (1 kHz sinewave)	
Output offset voltage	0.6 mV	
Full power bandwidth	15 Hz - 125 kHz (-3 dB)	
Slew rate	25V/us	
Damping factor	more than 400 (8-ohm load)	
Noise	-95 dB (input shorted)	
Total harmonic distortion (thd)	100 Hz	0.004 percent
(1 - 60 W into 8 ohms)	500 Hz	0.004 percent
	1 kHz	below noise
	10 kHz	0.038 percent

These are worst case figures, because the noise and thd measurements are not bandwidth limited and therefore contain contributions from mains hum and wideband noise. The apparent rise in distortion at higher frequencies also owes more to input/output cross coupling. This becomes more significant with increasing frequency, according to my fairly rudimentary home-made distortion analyser, than any non-linearities in the power amplifier. The power amplifier measures well when compared with the vast majority of commercially available power amplifiers and modules, where the performance figures tend to be optimistic rather than pessimistic, including some very expensive ones! The power amplifiers give more solid bass, a faster attack in the treble, and an overall feeling of being in greater control compared to my Blomleys.

This project has been well worth the effort for me. If you build one or more of these power amplifiers I hope that you'll agree. Enjoy!

Printed circuit boards

I have designed a single-sided printed circuit board for this project and the foils are given at the back of the magazine, as usual, for those of you who prefer to make your own pcbs. Power amplifiers usually have a long lifetime, so if you do make your own pcbs I would recommend sealing the copper side of the completed pcb with a spray on conformal coating, such as Maplin YB75S, to prevent corrosion of the copper tracks. Even better, you could tin-plate the newly etched pcb by dipping it into a tin plating solution for half an hour. Unfortunately tin-plating crystals do not seem to be available in small quantities, and a 450g pack from Farnell costs around £40!

However, for ease of component location, solderability, freedom from solder bridges, and long-term reliability I prefer, wherever possible, to use manufactured pcbs with silk screened component locations, tin plated tracks, and solder masking. Obviously this is not economic for pcbs in ones and twos, so I had a batch of pcbs professionally manufactured, and I can offer pcbs from this batch as follows:

Glass fibre, tin plated, solder masked pcbs with silk screened component locations for the mos100 power amplifier are available (by mail order only) for £15.99 each, or £29.99 per pair inclusive of UK delivery by recorded post. (VAT is not chargeable.) Please send cheques, drawn on a UK bank, for the appropriate amount to the author at:

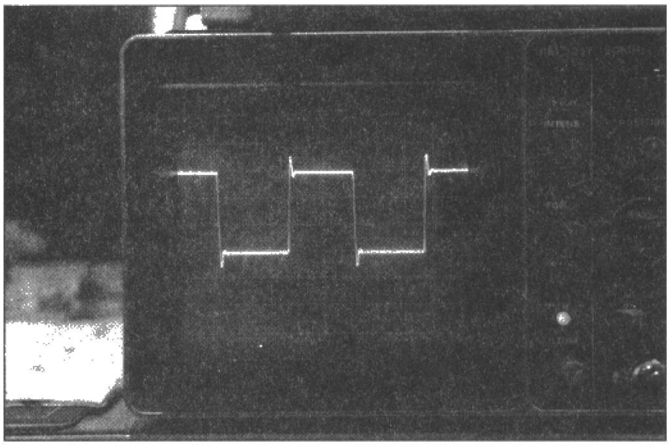


Photo 3e: the power amplifier output into an 8-ohm in parallel with a 0.1uF load (5V/cm).

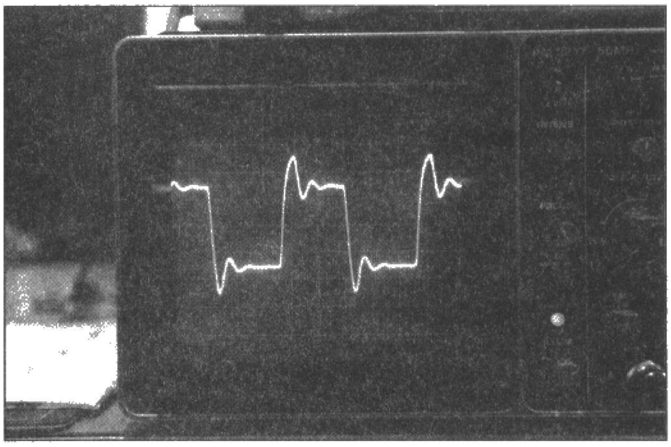


Photo 3f: the power amplifier output into a 4-ohm in parallel with a 1.0uF load (5V/cm).

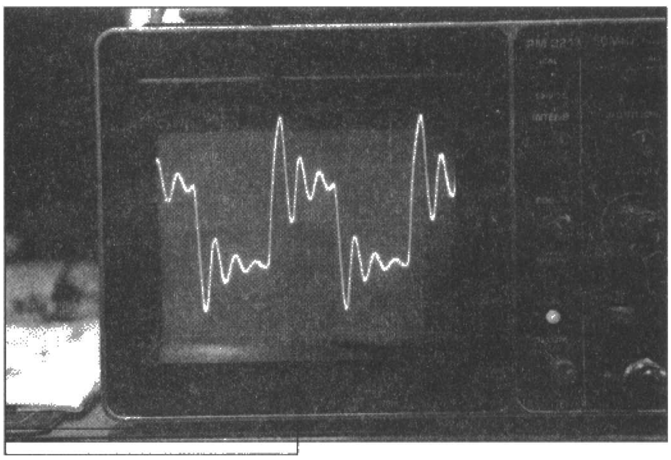


Photo 3g: the power amplifier output into an 8-ohm in parallel with a 1.0uF load (5V/cm).

Dr. D.N.J. White
11 Station Road,
Bearsden,
Glasgow G61 4AW

In addition, a range of high quality op-amps, matched sets of semiconductors, and complete kits of parts are available at attractive prices. Send a self-addressed, stamped envelope for details.

Getting MORE out of PICs

Part 3

Robin Abbott

Driving multiplexed and non-multiplexed 7-segment LED displays

This month we shall look at driving LED displays from a PIC. Although LED displays consume considerably more power than other display devices such as LCD displays or modules, they are cheaper, more visible, and much easier to program in software. We shall take a look at program routines for driving 4-digit LED displays, both in non-multiplexed and multiplexed modes.

The main consideration when designing an interface to an LED display is the number of pins available on the PIC. To drive a 4-digit LED display in non-multiplexed mode requires 28 pins, one for each segment. On a 40-pin PIC such as a 16C74, there are only 33 pins for input or output, and therefore this will leave only 5 pins for general-purpose use. It is, of course, possible to use LED drive pins for dual purposes, particularly when reading a keypad, however, this requires the capability to turn off the digit drive to the display while reading the pins. A multiplexed 7-segment LED display which is directly driven requires 7 pins (one for each segment), plus one pin for each digit in the display, so our 4-digit display requires 11 pins.

In this article I shall look at using additional circuitry to drive a multiplexed display with two pins for segment data plus one pin per digit, and a non-multiplexed display with just two pins of the PIC.

Driving a multiplexed LED display

As most readers will know, a multiplexed display is driven by turning on each digit in sequence. As each digit is turned on, the segment data driven from the PIC is set to the correct pattern for that digit. The drive pattern for a display showing the number 1234 is shown in **figure 1**.

There seems to be no set standard or view on the speed with which a multiplexed display should be driven. As good PC monitors have a refresh rate of 100Hz per frame to avoid flickering, this seems to be a good refresh rate to use for the LED display. Therefore our 4-digit display may be driven for 2.5 milliseconds per digit, allowing 10ms for the complete display to be shown.

As each digit is only illuminated for a quarter of the time that would be shown for a non-multiplexed display, it is usually necessary to increase the drive current for a multiplexed display. It is often possible to overdrive the display with a higher current drive than the maximum specified by the display manufacturer - some 7-segment display data sheets include maximum constant drive currents and pulse drive currents. If this technique is used, then it is important to reduce the current drive during development, and to use the PIC watchdog so that software failures or errors do not constantly turn on the LED drive to one or more digits which could damage the displays.

As an example, I decided to use the smaller general purpose PIC board which was presented in the first article in this series. This board has only nine input/output pins available for driving peripheral devices, as four pins are used for the serial interface

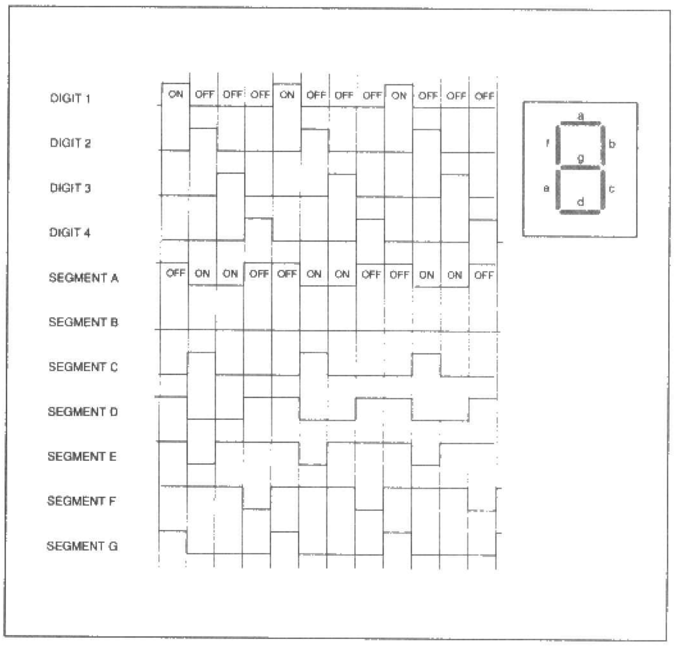


Figure 1: multiplexed display driving patterns

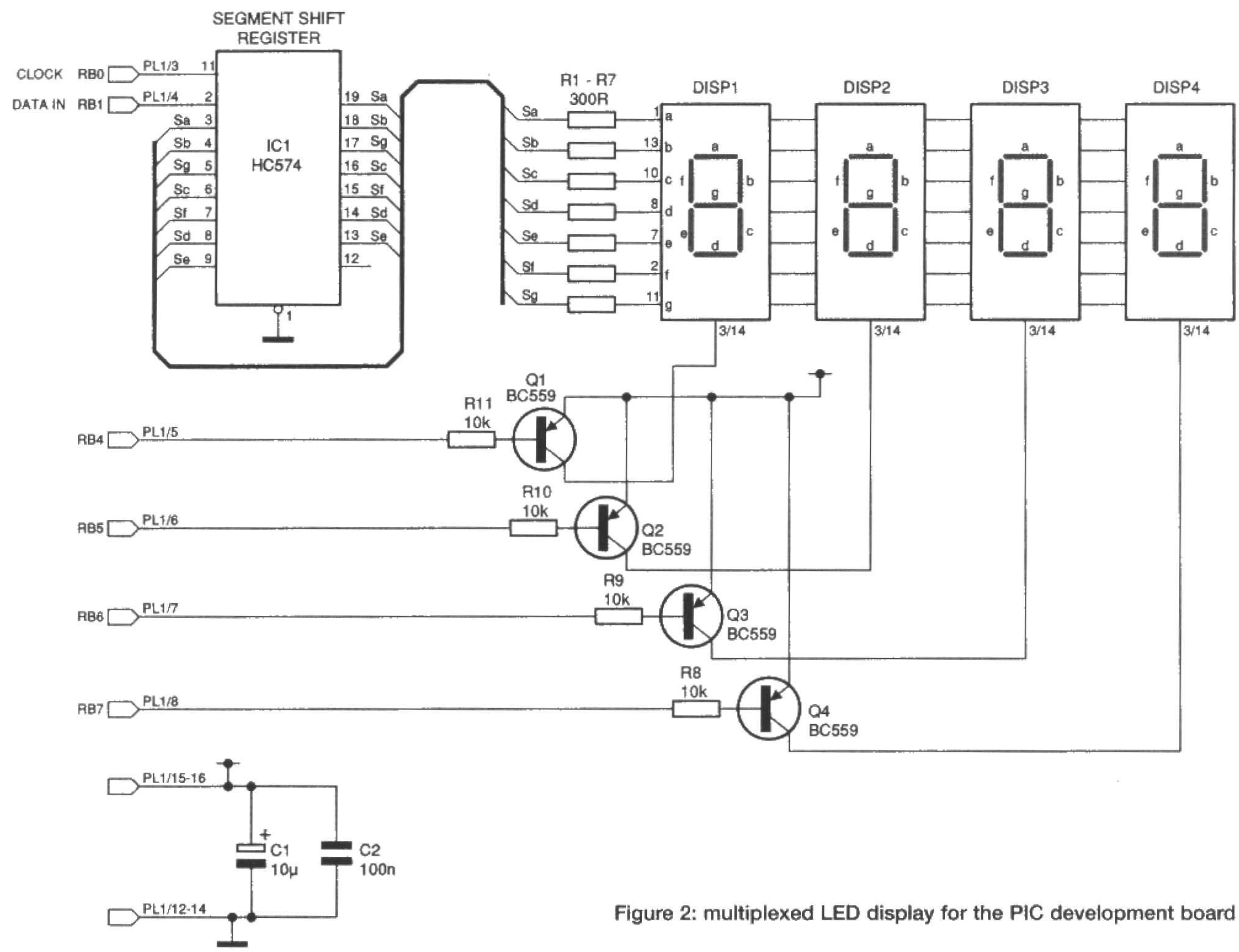


Figure 2: multiplexed LED display for the PIC development board

and I2C socket, but the 4-digit multiplexed display needs 11 pins. For this reason, I decided to use an external shift register to drive the segment data. This requires one pin to drive the clock input, and one pin to drive the data input. Each digit then requires a single pin to turn it on. The result is that the display requires only six pins to drive it at the cost of the external shift register, which is a standard low cost 74HC574 device in a 20-pin DIL package.

Figure 2 shows the circuit diagram of the display and the shift register. Each Common Anode digit is driven by a PNP transistor, and the segments are turned on by a low signal drive. The 54HC574 is an 8-bit latch with a common clock and enable signal. The enable signal is connected so that the outputs of the device are always enabled. Each latch Q output is connected to the D input of the next latch, so that the device forms an 8-bit shift register. Note that to assist PCB layout, the segments of the display are not driven in order from the shift register, so that although bits 0 and 1 of the shift register drive segments A and B, bit 2 of the shift register drives segment G. This is corrected in the software described below.

To use the display is a little more involved than for a straight segment drive. The four digit drives are all turned off. Then the segment data is clocked one bit at a time into the shift register, finally the next digit drive is turned on. It takes around 100us (microseconds) to update the display, and this is undertaken every 2.048ms in the example program so the overhead of the LED display is about 5 percent of the available PIC capacity with a 4-MHz clock.

A printed circuit board layout is shown in **figure 3**. The single-sided board is intended for experimental purposes. In practice, a double-sided board allowing the displays to connected more closely together would be preferable. The connection to the development board is made through a 16-pin dil socket which matches that on the

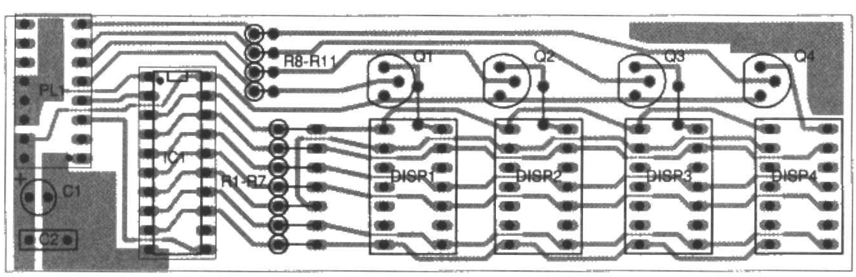


Figure 3: the component layout for the multiplexed display

development board. The board is simple to construct. Insert the links first - there are four links on the board. Follow this with the ic sockets (note that the 7-segment displays must be socketed, both to allow easy testing and replacement, and to lift them above the rest of the components). Finally insert the capacitors and resistors.

The link between the display board and the development board is made using a 16-way flat IDC cable to a 16-pin dil IDC header. The best way to make up the connector on the cable is to solder a 16-pin dil socket to a piece of scrap Veroboard. Insert the header pin assembly into the socket and assemble the rest of the header and the cable around the pins. The whole assembly may then be completed by squeezing the header gently together in a vice or mole wrench. Make sure that the red wire enters the header at pin one on both ends of the cable.

The test program

To test the display I shall present a simple program. This program will display the numbers included in four variables: digit1, digit2, digit3, and digit4 on the display. The numbers are held in decimal. Therefore if digit2 holds the number 06H, the number 6 is displayed on digit 2. The test program simply sets up the number 1234 to be displayed.

Listing 1 shows the variables used by the program and the initialisation and main interrupt routine. The variables temp and temp1 are used by the routine which drives the next digit to the display. The variable CurDigit is set to 0, 1, 2 or 3, and indicates which digit is currently being driven. The software sets up the ports of the PIC, initialises the digit drives and sets up the interrupts. It then enters an infinite loop. The software uses the inbuilt timer of the 16C84 to generate an interrupt every 2048us. Every time this interrupt occurs the digit is changed. The interrupt routine tests that the timer interrupt has occurred and if it has then it calls the DigitChange routine. Listing 1 also includes the standard 16C84 initialisation file.

Listing 1

```
#include "p16f84.inc"
#ifndef __PICDE
 processor 16f84
#endif

;
; Listing 1 - Initialisation and main interrupts
;
    cblock 0x0c
     intw               ; Storage during interrupt
     intflags
     Digit1             ; Data for Digits
     Digit2
     Digit3
     Digit4
     CurDigit           ; Current Digit
     Temp               ; Temporary registers
     Temp1
    endc

#define Data 3          ; Data and clock bits
#define Clock 2

     org 0
     goto Start

     org 4              ; Interrupt routine at
                          address 4
inthand movwf intw      ; Save registers
       swapf STATUS,w
       movwf intflags
       bcf STATUS,RP0
       btfss INTCON,T0IF
       goto CheckNext
       bcf INTCON,T0IF  ; Clear Timer 0 interrupt
       call DigitChange ; go to next Digit
       goto intret

CheckNext               ; Jump here to check other
                          interrupts

intret swapf intflags,w
       movwf STATUS
       swapf intw,f
       swapf intw,w
       retfie

; Initialise ports and interrupts

Start                   clrf INTCON
       movlw 1
       movwf Digit1     ; Data for test display
       movlw 2
       movwf Digit2
       movlw 3
       movwf Digit3
       movlw 4
       movwf Digit4
       movlw 0xf3
       movwf PORTB      ; All Digit drives off
       clrf TMR0
       clrf CurDigit    ; Start with Digit 1
       bsf STATUS,RP0   ; Upper memory page
       movlw 0xd2
       movwf OPTION_REG ; Timer 0 roll over every
                          2mS
       movlw 0x03
       movwf TRISB      ; Drive Port B bits
       bcf STATUS,RP0
       movlw (1<<GIE)|(1<<T0IE) ; Enable interrupts
                                  TMR 0
       movwf INTCON

Loop   goto Loop
```

Listing 2 shows the DigitChange routine. First, the current digit is turned off. Then the new segment data is read, and is written to the Temp variable using the GetSegment routine. This segment data is written to the shift register using the WriteShift routine. Finally the next digit is driven.

Listing 2

```
;
; Listing 2 - Digit Change routine
;

DigitChange movlw 0xf0
            iorwf PORTB      ; Turn off all Digits
            incf  CurDigit
            movlw 3
            andwf CurDigit   ; CurDigit counts
                               0,1,2,3,0,1...
            movfw CurDigit
            addlw Digit1
            movwf FSR
            movfw 0          ; Read value of digit
            call GetSegment  ; Get segment data
            call WriteShift  ; Write segment data
            movfw CurDigit
            movwf Temp
            incf Temp        ; Holds digit counter
                               1-4
            movlw 0xf7
            movwf Temp1      ; Temp1 holds digit
                               drive
            setc             ; Set Carry for rotate
GetDigitDrv rlf Temp1
            decfsz Temp
            goto GetDigitDrv
            movfw Temp1
            andwf PORTB      ; Write Digit Data
            return
```

Listing 3 shows the GetSegment routine. This routine uses the FSR register to read the value of the next digit, this will be a number from 0 to 9. The routine then uses a look up table to discover the pattern for the digit. The look up table

is called SegData. Note that each entry represents the pattern for that digit in 7-segment format. Note that the order of segments from LSB to MSB from the shift register is ABGCFDE and therefore this is the order of the bits in the table. To indicate that a bit is turned on, it has the value 0, and if it should not be turned on, the value is 1. For example, number 0 has all bits turned on except for segment G, and therefore the first entry in the table for the number 0 has the value 4.

Listing 3

```
;
; Listing 3 - Read segment data, value in W
;
;****
; WARNING if the value in W is less than 0 or
; is greater than 9 then the program WILL crash
;****
;
GetSegment  movwf Temp
            movlw SegData>>8
            movwf PCLATH        ; Set up upper bits
                                  of PC
            movfw Temp
            addlw SegData       ; Index from table
                                  start
            goto GetPC

GetPC       movwf PCL           ; Do the indirect
                                  jump
;
; Segment data, 0 to turn on Segment
;
; Segment order is :     'ABGCFDE'
;
SegData     retlw B'0010000'    ; Digit 0
            retlw B'1010111'    ; Digit 1
            retlw B'0001100'    ; Digit 2
            retlw B'0000101'    ; Digit 3
            retlw B'1000011'    ; Digit 4
            retlw B'0100001'    ; Digit 5
            retlw B'0100000'    ; Digit 6
            retlw B'0010111'    ; Digit 7
            retlw B'0000000'    ; Digit 8
            retlw B'0000001'    ; Digit 9
```

Listing 4 is the WriteShift routine, which simply sends the data which is read from the GetSegment routine to the shift register one bit at a time, MSB first.

```
Listing 4

;
; Listing 4 Write data in W register to shift
register
;
WriteShift  movwf Temp          ; Temp holds data
            movlw 7
            movwf Templ
            clrc
SegLoop     bcf PORTB,Data      ; Clear Data bit
            rrf Temp
            skpnc               ; Test bit
            bsf PORTB,Data
            bsf PORTB,Clock     ; Clock the data
            bcf PORTB,Clock
            decfsz Templ
            goto SegLoop
            return

end
```

Assembling the program

Put listing 1, listing 2, listing 3 and listing 4 together in order and assemble them using MPASM. The program may then be programmed to a 16C84 and tested.

Driving a non-multiplexed display

As shown above, to drive a non-multiplexed display requires a large number of pins on the PIC. Few PICs have so many pins free, and it is likely that in many applications you will end up with a multiplexed display for this reason alone. Non-multiplexed displays will usually be brighter, and can be used in situations with flickering background lighting, or where movement is involved.

Fortunately there are some devices available for direct driving of LED displays which have a large number of segments. These devices are also very useful for driving any type of output device, such as relays. The M5450 is a 40-pin IC which accepts data in the same serial format as some integrated LED displays (in fact, it is almost certainly the device used in those displays). It has 34 outputs, each of which can be set or reset on a 2-pin serial interface. The device operates with a start bit, the data bits, and then a stop bit, and it is only on the stop bit that the serially shifted data is transferred to the outputs. Thus, for LED displays there is no interference as new data is sent. The outputs are non-multiplexed, and the LED current can be set for all outputs with a single external variable resistor. The M5450 device has an output enable pin, and the M5451 device has an additional output bit. In the test application either can be used, but if the 5451 is used then pin 23 should be left open circuit (this is the output enable pin on the 5450).

Several of the M5450 devices can be driven with the same clock line, each device needing its own data line. Thus two 4-digit displays can be driven from three output pins on the development module.

The circuit diagram of a 4-digit LED display is shown in **figure 4**. The brightness of the LEDs is set using the variable resistor. To drive any other type of output device, the LED displays can be replaced by PNP transistors with 1k base resistors driven from the output pins. A circuit board has been designed for a 4-digit 0.3-in LED display.

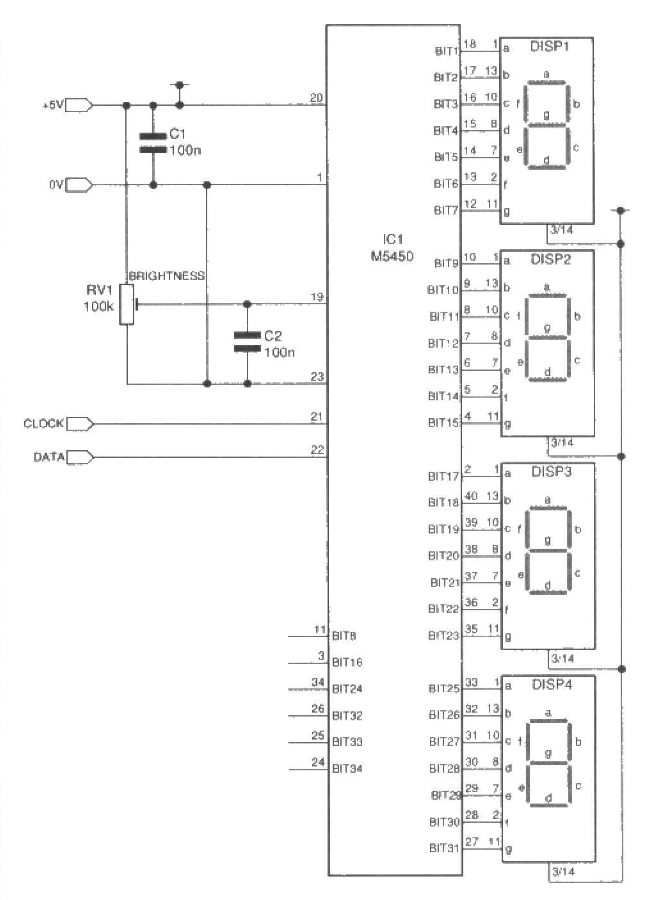


Figure 4: a non-multiplexed display driver

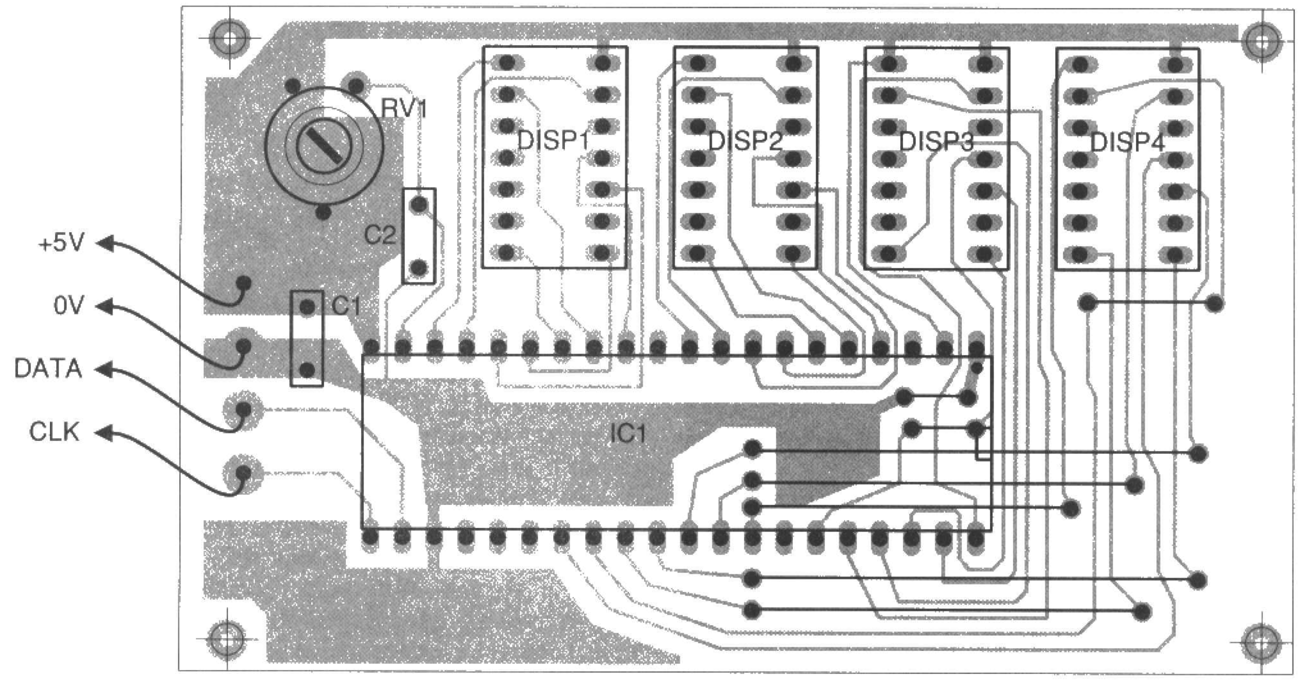


Figure 5: the component layout for a non-multiplexed display

The overlay is shown in **figure 5**. Construction is very straightforward. There are eight wire links, some of which must be fitted under the ic socket. A similar circuit board could be designed for bigger displays. Digit 1 is driven by the first eight bits sent to the display, digit 2 by the second eight bits, and so on.

To connect to the development board the four-wire interface is wired to a 16-pin dil socket which can be soldered on a scrap piece of Veroboard. The power supply pins on the socket are pin 11 for ground and pin 16 for +5V. The clock input is connected to port B bit 0 on pin 1 of the socket, and the data input to port B bit 1 on pin 2 of the socket.

The format of the data sent to the display is shown in **figure 6**. The clock can run continuously, or as in test the application that I will present below, runs only when data is sent to the chip. The first bit sent must be a level 1 which acts as a start bit, followed by the data to be sent to pin 18 - output bit 1, and then output bit 2 - and so on. There must be a total of 36 clocks sent, and on the 35th bit (the last clock) the data is transferred to the display. Further clocks may be sent although the data line should remain low.

Listing 5 shows the main part of a test program for the display. The test program writes the numbers 8756 to the display, and then the last digit cycles from 0 to 7 incrementing once per second.

Listing 5

```
#include "p16f84.inc"
#ifndef __PICDE
 processor 16f84
#endif

;
; Listing 5 - Initialisation and main interrupts
;
        cblock 0x0c
            Digit1              ; Data for Digits
            Digit2
            Digit3
            Digit3
            Digit4
            Temp                ; Temporary
                                  registers
            Temp1
            Temp2
            Delay0              ; 3 Delay variables
            Delay1
            Delay2
          endc

#define Data 1                  ; Data and clock
                                  bits
#define Clock 0

                org 0
                goto Start

                org 4           ; Interrupt routine
                                  at address 4

; Initialise ports and interrupts
```

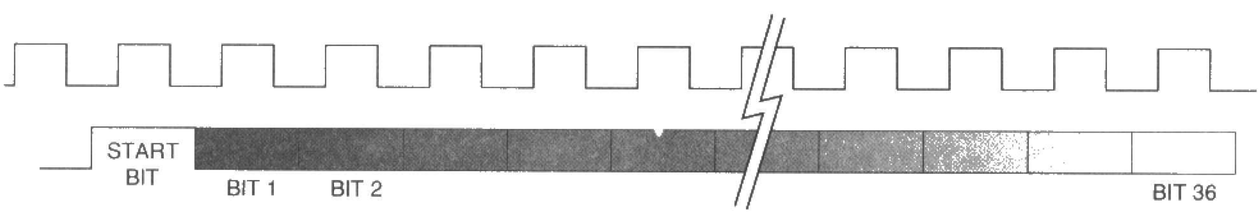


Figure 6: data format for the M5450

```
Start       movlw 9
            movwf Digit1        ; Data for test
display
            movlw 8
            movwf Digit2
            movlw 7
            movwf Digit3
            movlw 6
            movwf Digit4
            movlw 0xfc
            movwf PORTB         ; All Digit drives
                                  off
            bsf STATUS,RP0      ; Upper memory page
            movlw 0xfc
            movwf TRISB         ; Drive Port B bits
            bcf STATUS,RP0
            call ClearClocks    ; Clear shift reg on
                                  reset

            clrf Delay0
            clrf Delay1
            movlw .5
            movwf Delay2

Loop        call WriteLEDs
D0          decfsz Delay0
            goto D0
            decfsz Delay1
            goto D0
            decfsz Delay2
            goto D0
            movlw .5
            movwf Delay2
            incf Digit4
            movlw 0x7
            andwf Digit4
            goto Loop

;
; Send 40 clocks to the display to clear a pending
write on reset
;

ClearClocks   movlw .40
              movwf Temp
CCLoop        bsf PORTB,Clock
              bcf PORTB,Clock
              decfsz Temp
              goto CCLoop
              return
```

Again the variables digit1, digit2, digit3, and digit4 are used to hold the numbers to be displayed. The main routine includes the standard PIC16C84 header, and then sets up test data to the digits (the digits are set to show 8765 on the display). The main program also calls a routine also shown in Listing 5 called ClearClocks. This writes 40 clocks to the device while there is no data, clears the shift registers internally and sets up the device ready to receive data. Normally the M5450 resets when power is applied in a condition ready to receive data. However, it is important to use this routine as, if the PIC should be reset without resetting power (which may be as a result of software action or a watchdog reset), the PIC may have been in the middle of writing to the display. It is important that it completes this action before attempting to write new data.

Finally, the main test program calls the routine called WriteLEDS to update the display and enters an infinite loop. Unlike the multiplexed routine this program takes no processor time until the display digits are changed.

Listing 6 shows the WriteLEDs routine, this includes the look up table for the digits. This time however the table includes data for the segments which appear in the order ABCDEFG and so the table is different. Again the routine reads the correct data for each digit in turn and then writes it serially to the shift register in the 5450.

Listing 6

```
;
; Listing 6 - Write new value to the LEDs
;

WriteLEDs     movlw 4             ; 4 digits
              movwf Temp1         ; Digit Counter
              movlw Digit1
              movwf FSR
              bsf PORTB,Data
              bsf PORTB,Clock
              bcf PORTB,Clock     ; Clock start bit
DigitLoop     movfw 0
              call GetSegment
              movwf Temp          ; Segment data
              movlw 8
              movwf Temp2         ; Bit Counter
              rlf Temp
SendBitLoop   bcf PORTB,Data      ; Set data bit
              rlf Temp
              skpnc
              bsf PORTB,Data
              bsf PORTB,Clock
              bcf PORTB,Clock     ; Clock Bit
              decfsz Temp2
              goto SendBitLoop    ; Bit Loop
              incf FSR
              decfsz Temp1
              goto DigitLoop      ; Digit Loop
              movlw .10
              movwf Temp2
ClockLoop     bsf PORTB,Clock
              bcf PORTB,Clock     ; Clock Bit
              decfsz Temp2
              goto ClockLoop
              return

;
; Read segment data, value in W
;
;****
; WARNING if the value in W is less than 0 or
; is greater than 9 then the program WILL crash
;****
;
GetSegment    movwf Temp
              movlw SegData>>8
              movwf PCLATH        ; Set up upper bits
                                    of PC
              movfw Temp
              addlw SegData       ; Index from table
                                    start
              goto GetPC

GetPC         movwf PCL           ; Do the indirect
                                    jump
;
; Segment data, 1 to turn on Segment
;
; Segment order is :     'ABCDEFG'
;
SegData       retlw B'1111110'    ; Digit 0
              retlw B'0110000'    ; Digit 1
              retlw B'1101101'    ; Digit 2
              retlw B'1111001'    ; Digit 3
              retlw B'0110011'    ; Digit 4
              retlw B'1011011'    ; Digit 5
              retlw B'1011111'    ; Digit 6
              retlw B'1110000'    ; Digit 7
              retlw B'1111111'    ; Digit 8
              retlw B'1111011'    ; Digit 9
```

Assembling the program

Put listing 5, and listing 6 together in order and assemble. The program may then be programmed to a 16C84 or 16f84 and tested.

In the next issue

In next month's article we shall look at driving LCD displays.

Obtaining software

The software listings for this month and last month's articles should be available on the ETI web site at http://www.aaelectron.co.uk/eti/, and will be available on a disk from the author at the end of the series.

Tiny Traffic Lights

Terry Balbirnie's lights sequencer is designed to give "real traffic light" sequence timing and can drive a variety of led or filament lamp sizes

These model traffic lights will come in useful for anyone making displays involving road layouts (possibly for use with a model railway) or for teaching road safety. When the circuit is switched on, the lamps operate through the standard UK traffic light sequence and repeat indefinitely as long as a supply exists. The "red" and "green" time periods are relatively long compared with the "red and amber" and "amber" time period, which mimics realistic traffic lights in operation. The time taken for the circuit to cycle through the entire sequence is adjustable from a few seconds to one minute approximately. In practice, a period of about 20 seconds looks the most convincing.

Power supply

The Tiny Traffic Lights operate from a nominal 9V supply, and you will get a satisfactory lifespan from an alkaline PP3-type battery. However, for long periods of operation, a more substantial battery such as a PP9 would serve better. It would also be possible to operate the unit continuously using a plug-in adaptor. The circuit will continue to work with satisfactory brightness down to about 6V.

In tests on the prototype circuit, I got good results using LEDs. The advantage of these compared with filament lamps is that they come straight from the shop in pretty well the correct colours and so don't need fiddly filters made of coloured plastic. I found that an orange LED in the "amber" position looks more realistic than a yellow one. LEDs are available in several diameters: 3mm, 5mm, 8mm and 10mm, which allows models of various sizes to be built as appropriate.

For a large model, 6V filament bulbs of, say, 60mA rating could be used instead with only a small modification to the circuit. The standard MES type mounted in miniature lamp holders will probably be most suitable. Filament lamps would need pieces of coloured plastic or some other form of coloured filter placed in front of them to provide the correct colours, and that required suitable mounting so that the lamps don't heat up the filters.

The circuit is given here as a bald PCB - that is, no actual model was constructed. This is because anyone using this circuit will be likely to have a particular application in mind and their own ideas about how it should be constructed. In most cases, the circuit panel and battery will be placed in a box which will act as a stand for the traffic light head and be mounted on the end of a piece of plastic or metal tubing and suitably painted. The four wires (to red, orange and green LED cathodes plus a common positive) leading to the head will then pass up the tube. For a larger model, the PCB could perhaps be accommodated inside the head with only the power supply wires passing up the tube.

The circuit

The circuit for the Tiny Traffic Lights is shown in **figure 1**. A supply is established to the main section (but not the LEDs) through diode D12. This diode operates in conjunction with C4 to hold a reserve of charge and encourage correct operation, especially when the battery has aged somewhat. The timing section consists of an astable centred on the cmos timer IC1 and its associated components. As long as a supply is connected, the output (pin 3) will go repeatedly high and low with the time period set by the values of R1 and R2, preset RV1 and C2. With RV1 set to minimum adjustment, the output pulses at a rate of about three per second. Set to maximum, they appear at six-second intervals approximately.

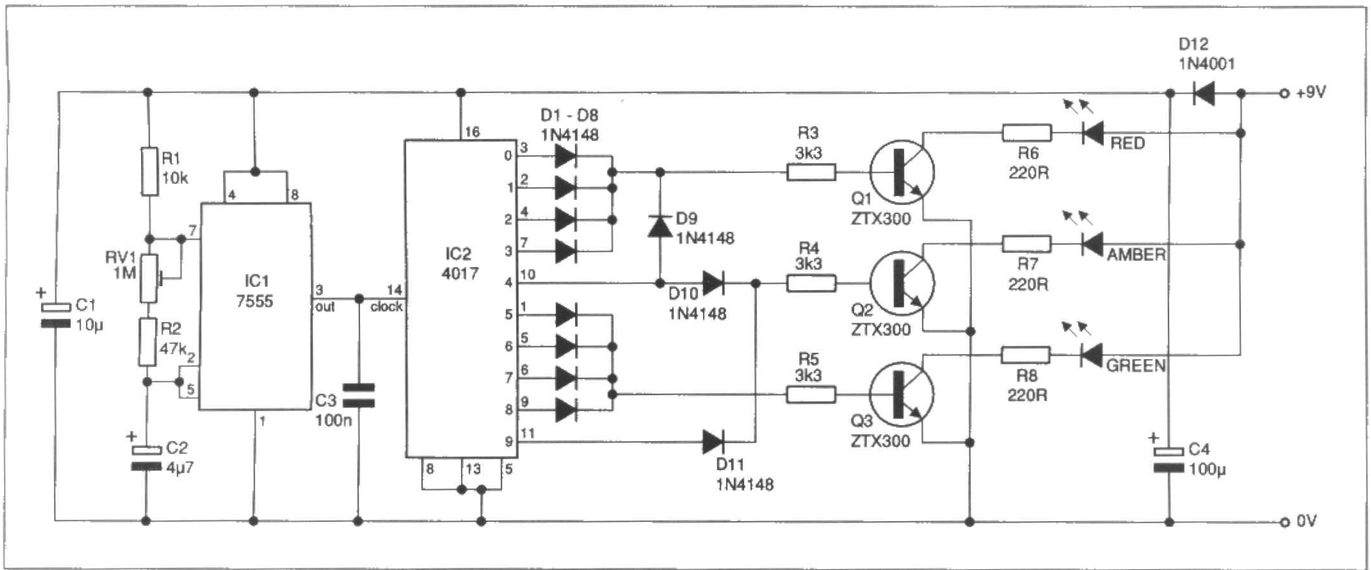
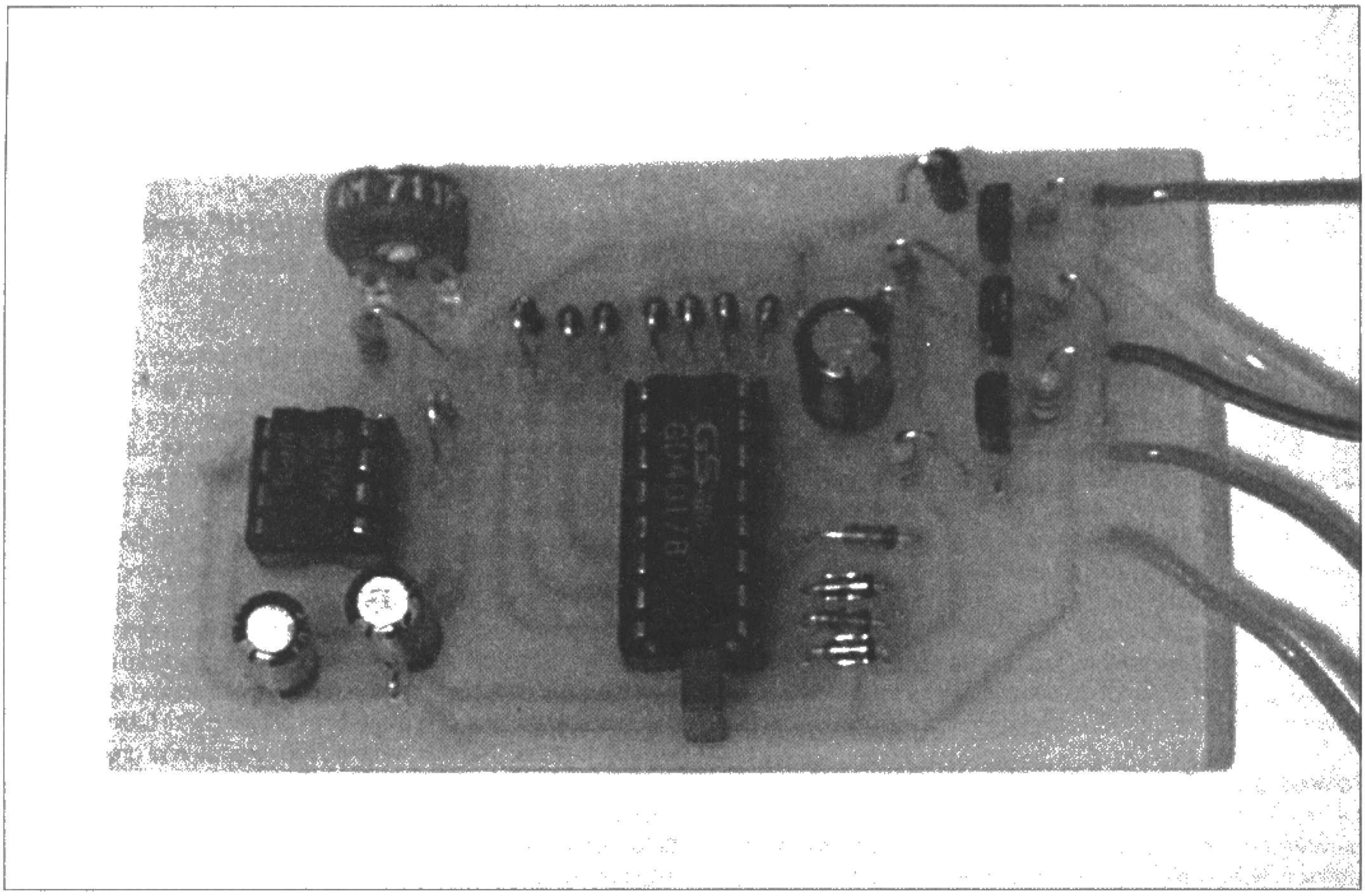


Figure 1: the circuit of the Tiny Traffic Lights



The output of IC1 is connected to the clock input (pin 14) of the decade counter, IC2. As each positive pulse arrives, the ten outputs (0 to 9 within IC2) go high in turn repeatedly. The pins corresponding with these outputs are 3, 2, 4, 7, 10, 1, 5, 6, 9 and 11 respectively. D1 to D4 act as a 4-input OR gate. When output 0, 1, 2 or 3 is high, a signal passes via the appropriate diode through R3 to the base of Q1. The transistor turns on for four astable pulses and the red led in its collector circuit operates, with R6 limiting the current. When IC2 output 4 (pin 10) goes high, D9 and D10 conduct. D9 passes a high state to R3 so that Q1 and the red LED continue to operate. Meanwhile, D10 passes current to the base of Q2 via R4. The transistor turns on and the orange LED lights via current-limiting R7. This provides the "red and amber" aspect. This is followed by IC2 outputs 5 to 8 going high with D5 to D8 acting as a 4-input OR gate. As each one conducts, current passes through R5 and turns on Q3. This causes the green LED to light through current-limiting R8. The sequence ends when IC2 output 9 (pin 11) goes high and allows D11 to conduct. A signal is applied to R4, which causes the amber LED to operate alone. Note that the "red and amber" and "amber" stages occupy only one astable pulse while "red" and "green" occupy four. In every case, when a diode conducts, the other diodes in the group are reverse-biased and prevent a back flow of current into IC2 outputs.

The copper track on the PCB which links IC1 pin 3 and IC2 pin 14 is fairly long. It is therefore vulnerable to the pick-up of stray signals (particularly from the 50Hz field from nearby mains equipment). C3 bypasses any such signals. Without it, triggering tends to be erratic. Note that IC2 automatically resets when the circuit is switched off and will start again by output 0 going high, so the lights will always begin from "red" when the circuit is first powered up.

The reason for using "diode logic" rather than a system of ic logic gates was to simplify the pcb design. It is also very cost-effective. The transistor base resistors, R3, R4 and R5, have such a value that it should be possible to use 6V or 6.5V filament lamps of up to about 150mA rating instead of LEDs. However, to minimise the current requirement, it would be better to use bulbs of 60mA rating maximum. If you are using filament lamps, the current-limiting resistors R6, R7 and R8 would not be required. This is the modification referred to earlier and more will be said about it below.

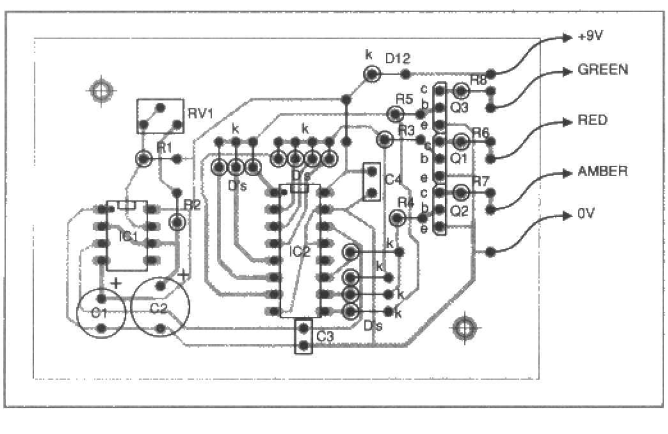


Figure 2: the component layout

Construction

Before beginning construction work, give some thought to how the model will be constructed. If you want to use filament lamps, first find suitable pieces of transparent coloured plastic to use as filters - sweet wrappers are one well-known source, for example. If you are using LEDs, decide on the size you want for the scale of your model.

The PCB layout of the Tiny Traffic Lights is shown in

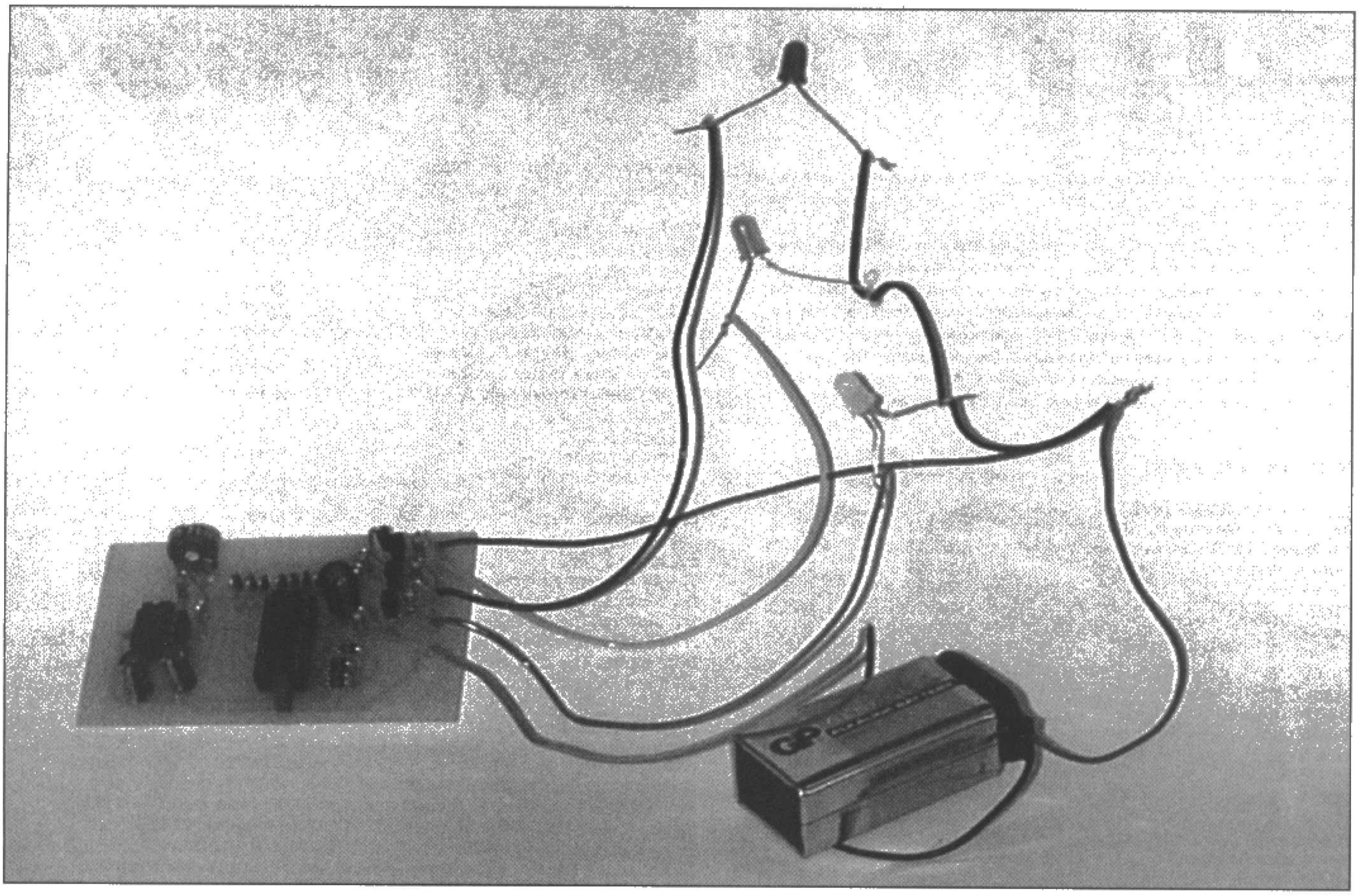


figure 2. Begin by drilling the two mounting holes as indicated. Follow with the ic sockets, the link wire then all other components. The eleven "D" positions are all 1N4148s (D1 to D11). As usual, check the polarity of the diodes, transistors and capacitors C1, C2 and C4 carefully. If you are using filament lamps, leave out R6, R7 and R8 and connect the corresponding wires to the left-hand points which would have been occupied by them so that the wires are connected direct to the transistor collectors. These wires will only be used for testing and will be replaced by more appropriate lengths of wire when the circuit is being wired up in the actual model. If you are using LEDs, solder pieces of stranded connecting wire to the points labelled "red", "amber", "green" and also to the "+9V" and "0V" points. The complete PCB is shown in the photograph.

Adjust RV1 fully anti-clockwise to give minimum timing for testing purposes. Insert the ics in their sockets the right way round. Observe static precautions by touching something earthed (such as a water tap) before handling the cmos ic pins.

Connect the LEDs to the circuit panel wires temporarily by twisting them on to the leads. Note that the cathode ends, that is, the shorter end lead or a "flat side" on the body, which are connected to the wires from the PCB. The anode leads are connected together using a short piece of wire. Connect the common LED wire to the "+9V" wire leading from the PCB. Connect this to the positive wire of the battery connector. Connect the "0V" wire to connector negative. Take care not to cause short-circuits at any of these connections. Connect up the battery. The red LED should come on and the display run through the traffic light sequence rather quickly. If all is well so far, adjust RV1 so that the sequence rate is as you want it.

The circuit should now be ready for the mounting of your choice. Fit a switch in the supply positive to turn the circuit off after use.

PARTS LIST for the Tiny Traffic Lights

Resistors

R1	10k
R2	47k
R3, 4, 5	3k3
R6, 7, 8	220R
RV1	1M sub-min preset - vertical.

Capacitors

Electrolytics 16V or more

C1	10u electrolytic
C2	4.7u electrolytic
C3	100n 2.5mm pin spacing
C4	100u electrolytic

Semiconductors

IC1	7555
IC2	4017
Q1, Q2, Q3	ZTX300
D1 to D11	1N4148
D12	1N4001

Miscellaneous

Red, orange, green LEDs or filament bulbs (see text). 8-pin dil socket; 16-pin dil socket. 9V battery and connector - see text. SPST toggle or rocker switch. All components for this project may be obtained from Maplin Electronics.

ETI ELECTRONICS TODAY INTERNATIONAL PCB Service

ETI can supply printed circuit boards for most of our current projects - see the list below for boards available. For recent boards not listed, check the constructional article for an alternative supplier.

Please use this order form or a copy of it. Check that all relevant information is filled in, including the Unit Order Code, and that you have signed the form if sending a credit card number. Overseas customers please add postage appropriate to the number of units you are ordering. Make cheques/POs/money orders, in £ sterling only, payable to Nexus Special Interest Limited. Please allow 28 days for delivery. Access/Visa orders may be made on 01442 266551 (ask for Readers Services).

Only boards listed here are available from our PCB Service. For past issues of magazines, or binders, please see page 74 or contact Readers Services for information.

Name and issue of project	Unit code	Price
ETI PCB Service Issue 8 1998		
PIC Electronics Security Switch	E/898/1	£5.09
PIC Multiplexed LED Display	E/898/2	£5.09
PIC Non-multiplexed LED Display	E/898/3	£5.09
Easy Parker	E/898/4	£6.77
Tiny Traffic Lights	E/898/5	£5.09
Q Meter	E/898/6	£5.09
Bath Duck	E/898/7	£5.50
ETI Issue 7 1998		
PIC 16C74 Development Board	E/798/1	£5.09
Surface Mount Diagnostic Interface	E/798/2	£5.09
Surface Mount Logic Probe	E/798/3	£5.09
Mains Monitor	E/798/4	£12.33
Aquaprobe	E/798/5	£5.50
ETI Issue 6 1998		
PIC Development Board	E/698/1	£5.50
Signal Generator	E/698/2	£8.99
Headlight Delay Unit	E/698/3	£5.50
6-Interval Games Timer	E/698/4	£5.09
ETI Issue 5 1998		
UHF Transmitter (DS)	E/598/1	£5.07
UHF Transmitter Encoder	E/598/2	£5.09
UHF Receiver Front End (DS)	E/598/3	£5.07
UHF Receiver IF stage (DS)	E/598/4	£5.07
Fridge Thermometer	E/598/5	£5.50
AVR Controller	E/598/6	£5.50
27C16 Eprom Programmer	E/598/7	£7.87
Guardian Light	E/598/9	£6.22
ETI Issue 4 1998		
LED Voltmeter	E/498/1	£5.64
BB Ranger Control Board	E/498/2	£6.22
BB Ranger Score Board	E/498/3	£22.89
Line-Up Oscillator with Glitch	E/498/4	£8.99
Tic Tac Toe	E/498/5	£8.44
ETI Issue 3 1998		
Medium Wave Loop	E/398/1	£5.64
AA Cell Eliminator	E/398/2	£7.32
PIC Based Double Bass Tuner	E/398/3	£5.64
5 Range Capacitor Meter	E/398/4	£6.77
MIDI Drum Pads	E/398/5	£5.64
ETI Issue 2 1998		
Smartcam main board	E/298/1	£5.09
Smartcam opto-sensor board	E/298/2	£5.09
Both smartcam boards	E/298/1&2	£7.00
Switched Mode Internal Power Supply	E/298/5	£7.87
Auto Cupboard Light	E/298/3	£5.64
ETI Issue 1 1998		
Control Centre Desk-Top Unit	E/0198/1	£8.99
Control Centre Main Section	E/0198/2	£7.87
ETI Issue 13 1997		
4-Go Rocket Launcher - main board	E/1397/1	£5.64
4-Go Rocket Launcher - relay board	E/1397/2	£6.22
Mighty Midget	E/1397/3	£9.54
ETI Issue 12 1997		
PC Phonecard Reader: ITT Cannon only	E/1297/1	£6.22
Minute Minder	E/1297/2	£13.98
Medium Wave Receiver - RF board	E/1297/3	£11.76
Medium Wave Receiver - Tuning board	E/1297/4	£5.09
Medium Wave Receiver - Audio board	E/1297/5	£5.09
Medium Wave Receiver - PSU board	E/1297/6	£6.77
ETI Issue 11 1997		
Total Harmonic Distortion Meter	E/1197/1	£13.43
Alphanumeric Morse Touchkey	E/1197/2	£5.09
ETI Issue 10 1997		
The IQ Tester	E/1097/1	£5.64
Fake Flasher	E/1097/2	£5.09
DC Motors (Part 2)	E/1097/3	£6.77
Valve Tester - Main Board	E/1097/4	£21.22
Valve Tester - Socket Board	E/1097/5	£5.09
Valve Tester - Heater Regulator	E/1097/6	£5.09
All three Valve Tester boards	E/1097/4/5/6	£30.30
The IQ Tester (previously E/897/2	E/1097/7	£5.64
ETI Issue 9 1997		
Eprom Emulator	E/997/1	£16.49
The Power Supply	E/997/2	£5.09
Electronic Door Chimes	E/997/3	£5.09
Digital Power Supply	E/997/4	£10.11
ETI Issue 8 1997		
The Brake Light Tester	E/897/1	£5.09
DC Motors (3 experimental boards)		
DC Motors: The first Control Unit	E/897/3	£5.09
DC Motors: The 4046 Circuit	E/897/4	£5.09
DC Motors: The Crystal Drive Circuit	E/897/5	£5.09
All three DC Motors boards	E/897/3/4/5	£11.50
ETI Issue 7 1997		
Eprommer: main board (double sided)	E797/1	£13.32
Eprommer: PSU board	E797/2	£5.64
Eprommer: personality modules (double sided):	E797/3	

Any ONE module board: £5.09; two modules: £7.90; three modules: £11.85; four modules; £15.80: five modules: £19.75; All six modules: £23.70

Please specify which Eprom modules you require. Modules are for 2716, 2732, 2764, 27128, 27256 or 27512. One order code/overseas postal charge applies whether a selection or all six personality module boards are ordered.

Are Your Lights On?	E/797/4	£5.09
Peak Reading VU Meter	E/797/5	£5.09

Terms of trade

Terms strictly payment with order. We cannot supply credit orders, but will supply a proforma invoice if requested. Proforma orders will not be processed until payment is received. All boards are manufactured from the foils that appear in the ETI Foils Pages for the appropriate issue. Please check that our foils are suitable for the component packages you intend to use before ordering as we cannot supply modified boards or replace boards that have been modified or soldered. Boards are only supplied in the listed units. Sorry, we cannot break units. Prices and stock may be altered without prior notice. Prices and stock listed in this issue supersede prices and stock appearing in any previous issue. ETI, Nexus Special Interests and their representatives shall not be liable for any loss or damage suffered howsoever arising out of or in connection with the supply of printed circuit boards or other goods or services by ETI, Nexus Special Interests or their representatives other than to supply goods or services offered or refund the purchaser any money paid in respect of goods not supplied.

Please supply:

Quantity	Project	Unit Order Code	Price	Total price

Prices are inclusive of post and packing in the UK. Overseas Post and Packing (if applicable): Add £1 per unit

Name ....

Address ....

I enclose payment of £ .... (cheque/PO/money order in £ Sterling only) to:

PCB Service, READERS SERVICES DEPARTMENT, Nexus Special Interests Ltd., Nexus House, Azalea Drive, Swanley, Kent BR8 8HU

Signature: ....

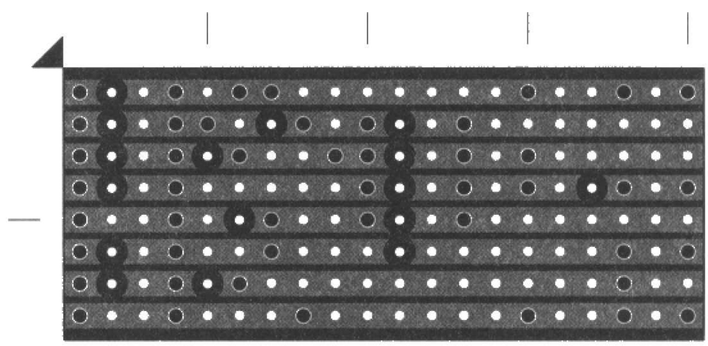
Card expiry date: ....

Fast Fivers

Adaptable, affordable - handy circuits for around £5. By Owen Bishop

A touch lamp

There are many final forms this project could take, and we leave this aspect to your imagination and skills. We thought of it as a small, almost cubical, box of transparent plastic. There are no external fittings except for a metallic touch plate on the top surface. Inside is the circuit board, the battery pack and the lamp. The lamp is a torch bulb run at full power (or slightly over-run to give added brilliance) and its light freely escapes from the box. You could keep it on the bedside table. In the dark you have only to reach out and contact the touch plate to illuminate the room.



How it works

This is a very simple circuit, and very fast to build too. The touch plate is wired to the trigger input of a 7555 timer (**figure 1**, IC1). This input is very sensitive to voltage level, which needs to fall only to two thirds of the supply voltage in order to trigger the timer. Touching it with a finger will temporarily reduce the charge on the plate and trigger the circuit. The plate is held at +6 V by the pull-up resistor R1, which has high value so as not to reduce the sensitivity of the input unduly.

The timer is wired as a monostable, to give an output pulse about 100 microseconds long. The exact length of the pulse does not matter provided it triggers the next stage of the circuit into action.

The next stage is a J-K flip-flop (IC2). The J and K inputs are held at 6V which gives the flip-flop a toggle action. At each succeeding rise of the clock input the output changes state from low to high or high to low. The output goes to a transistor which acts as a switch to control the lamp LP1.

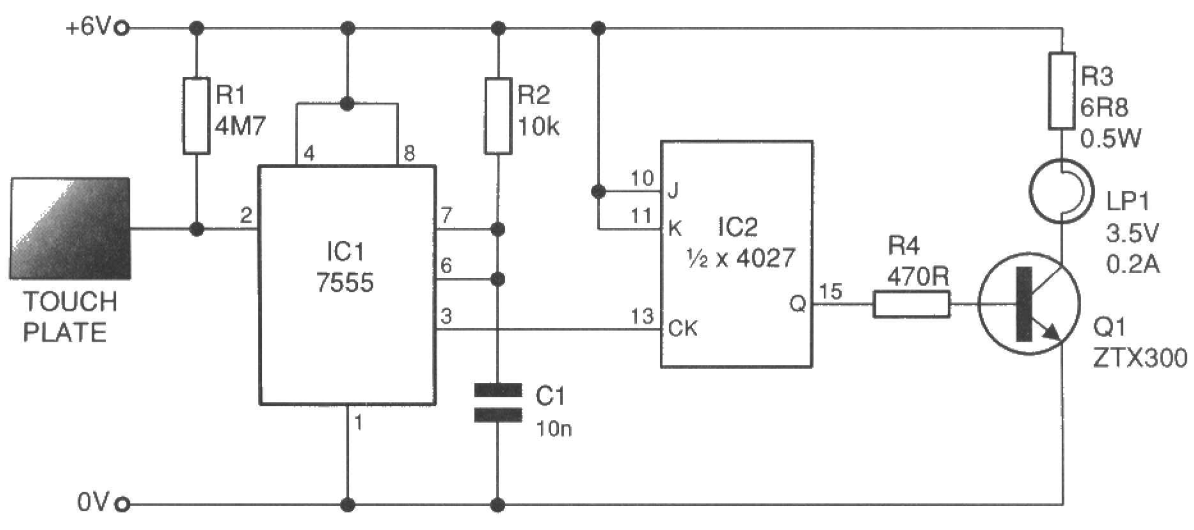


Figure 1: the circuit diagram of the Touch Lamp

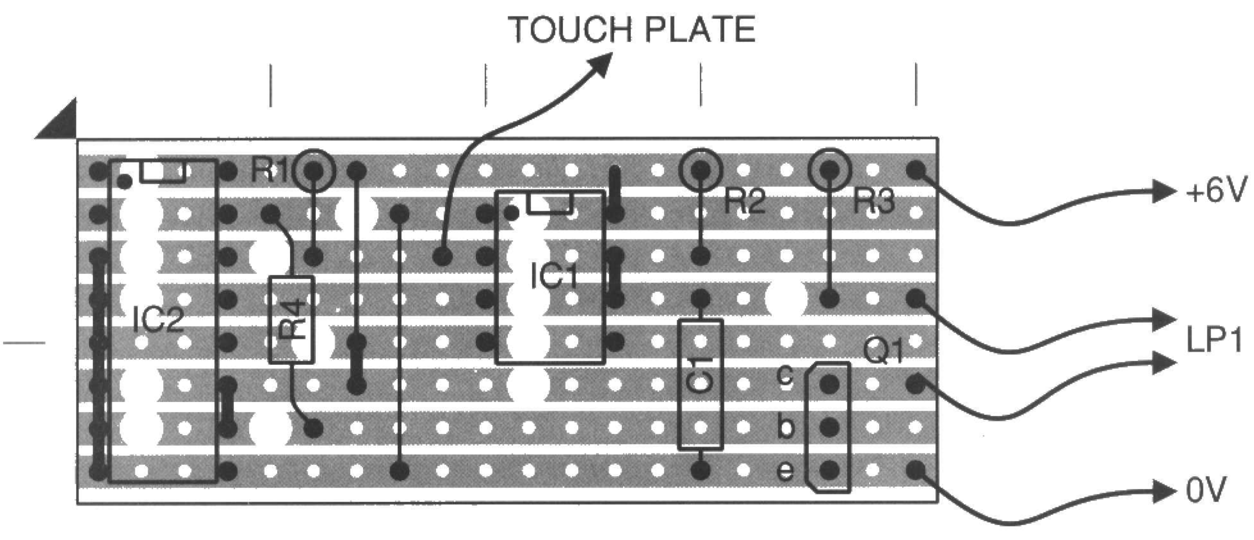


Figure 2: the stripboard layout

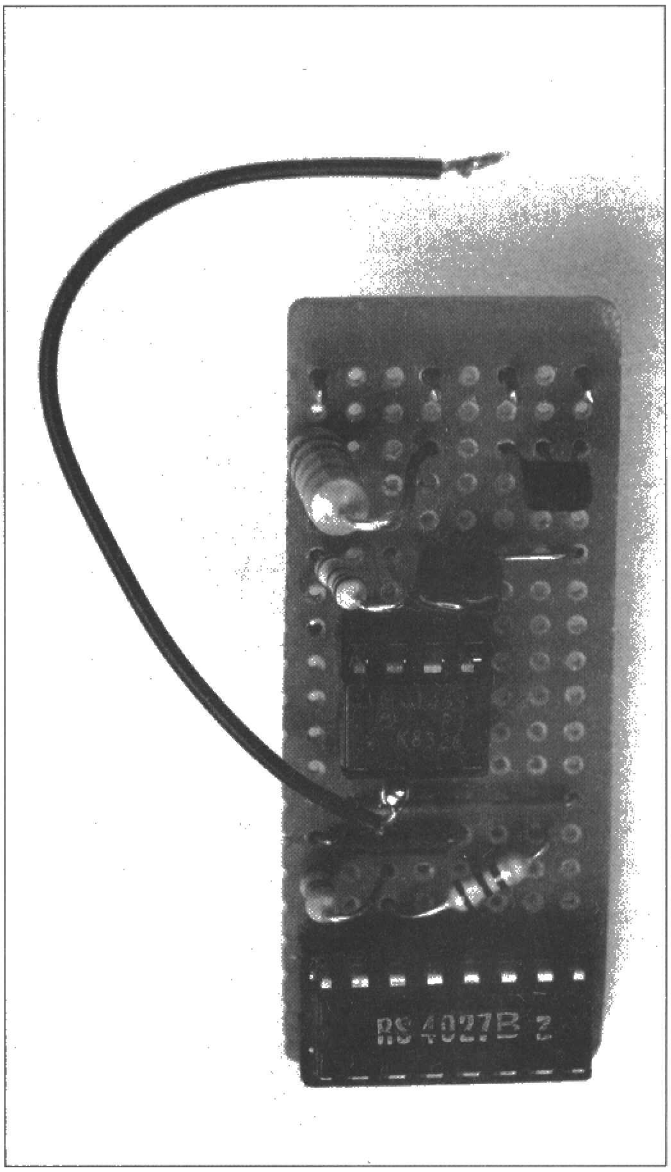
Lamps

There is a resistor R3 in series with the lamp to limit the current through it to about 200 mA, which is the maximum current for MES 3.5 V lamps. It is possible to omit this resistor, to over-run the lamp for added brilliance and shortened life. If slightly less than full brightness is acceptable, omit the resistor and substitute a 6 V lamp. Another type of lamp that could be used is the krypton bulb which give a very bright light, though it has a life of only 15 to 20 hours. These are available for a number of operating voltages. You could use either a 4.8 V or a 6 V lamp. Their current requirements are higher (around 700 mA) so a transistor of higher rating is essential. Also, since the cmos gate can not deliver the current (around 7 mA) needed to switch on a bipolar transistor handling as much as 700 mA, you should use a power mosfet, such as a VN66AF. This can carry 2A and will fit in place of Q1 in figure 2. R4 can be omitted as no significant current flows to the gate of the transistor.

Construction

The circuit is laid out as compactly as possible (see **figure 2**) to make it easier to fit inside any transparent box that you may have handy. Wiring is minimised by making as much use as possible of the copper tracks of the board, with solder bridges to make many of the connections. There are solder bridges joining A13 to B13, C13 to D13, E7 to F7, F4 to G4, and all the ic pins from C1 to H1. The reason for joining so many pins of IC2 is that IC2 contains two flip-flops, and it is essential to connect all unused inputs of a cmos ic either to 0 V or to the positive rail. Note that the copper strips beneath the ics are NOT cut at E2 and H2.

There are several ways of making the touch plate. It can be any reasonable size, the minimum being about 20 mm square and the maximum about 100 mm square. You can use any convenient thin sheet of copper, tinned iron, or aluminium or a scrap of plain unetched circuit board. If you



have the chemicals and equipment, you could design and etch a fancy touch-plate. We used aluminium kitchen foil, which is not as durable as other materials but is easily fixed flat to the plastic box top with double-sided adhesive tape.

Attach the connecting wire to the plate by drilling a small hole through plate and box top. Then pass a bolt through the hole, and add a solder tag and nut on the inside. Solder the connecting wire to the tag and run it to the pin at C9.

The values of R2 and C1 are not critical. If you have a spare capacitor of a value in the order of 10 nF, such as 5.6 nF, you can use this instead.

It is best to complete the circuit before testing it. You will probably not be able to detect the pulse from the time unless you have an oscilloscope but this is no matter. The proof of the circuit is that the lamp toggles between on and off each time you touch the plate. Touch-switches, though simple in concept, are tricky to operate. This circuit really needs to be a bit more complicated to make it entirely reliable. So do not expect the circuit always to toggle on the first attempt. Generally a short but definite tap on the plate produces the required result.

If all is working correctly, mount the various parts of the circuit in the box. The battery box and circuit board may be fixed inside the box using double-sided adhesive pads (such as 'Sticky Fixers'). Position the lamp socket so that it directs the light horizontally. You may prefer to use a lens-ended lamp to give a more concentrated beam, or perhaps include a reflector taken from an old electric torch.

PARTS LIST *for the Touch Lamp*

Resistors

5 percent 0.25 W unless stated

R1	4.7M
R2	10k
R3	6.8R, 0.5 W (maybe not needed, see text)
R4	470R (maybe not needed, see text)

Capacitor

C1	10n polyester or similar

Semiconductors

IC1	7555 cmos timer ic
IC2	4027 cmos dual J-K flip-flop ic
Q1	ZTX300 npn transistor, or similar (or one of higher power, see text)

Miscellaneous

LP1	3.5 V, 200 mA, MES cap (or other)

Lamp-holder to suit LP1, matrix board 22 mm by 55 mm (8 strips by 20 holes), 5 x 1-mm terminal pins, 8-pin ic socket, 16-pin ic socket, 6V battery holder for 4 AA cells, battery clip to suit battery holder, transparent box approximately 85 mm x 55 mm x 45 mm, materials for making touch plate and mounting circuit items in the box.

ETI New Technology Report

Great GrandSon of 555

The classic 555 timer has appeared in a new variant from Zetex Inc. in the USA, 25 years after its first launch. Everyone's friend, 'perhaps only equalled in fame by the 741 op-amp' according to Zetex's Dave Brotton and Adam Knight (and many other users), the 555 timer has during most of its lifetime been manufactured in greater volumes than any other linear ic

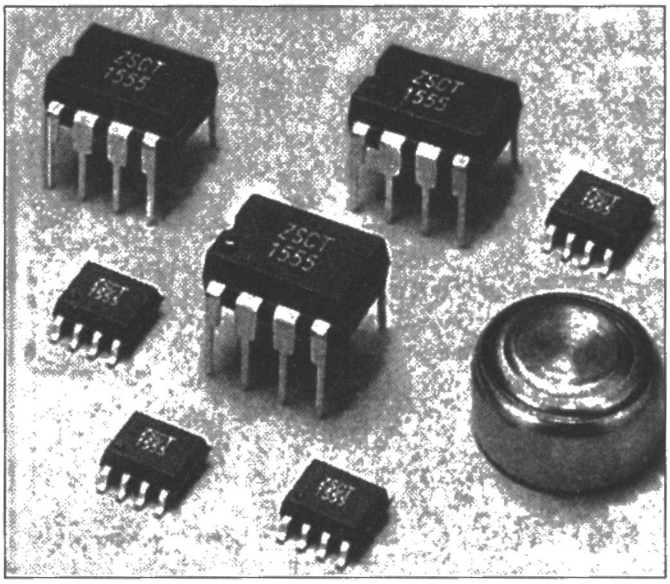
Named the ZSCT1555, the new timer has been designed to satisfy the needs of lower power, lower voltage and more portable applications, by offering single battery cell operation, guaranteed working down to 0.9 volts and bipolar technology.

The ZSCT1555 has the same 8-legged pin-out, 100 percent compatible with the standard 555 device, and with the simple adjustment of external components to set the frequency, has the same precision-timing functionality, whether generating accurate time delays, or oscillations.

Perhaps the most important aspect of the new version is its guaranteed operation down to 0.9 volts, better than any cmos alternatives. The demand for ever-decreasing power levels, lower supply voltage and smaller packages forces ic designers to search for more economical solutions. The ZSCT1555's enhanced electrical performance means that it can run easily from a single cell, and suits virtually any battery-powered or low-voltage equipment design. Power economy is further improved by low current consumption. Though the ZSCT1555 is a bipolar device, it exceeds CMOS performance in this respect too. Assuming a 5V supply, a typical CMOS part draws 170uA while the new timer pulls 140uA at 5V and just 75uA at 1.5V.

Other improvements in the single-cell timer include improved output pulldown current, improved thermal performance with a better temperature coefficient, and an operating temperature range specified to match with a wide variety of batteries.

The 555's popularity over the years has been based on flexibility, performance and great application versatility (as well as low cost). As the demands placed on components have changed over the years, the performance of the standard 555 has become stretched to its limits, and the potential for a revised design became clear. The original timers are used in applications with 5-volt supplies or higher, whereas today's equipment tends to use 3.3- and 3-volt supplies or



lower. The move to low power circuits and the increased use of batteries meant that the original 555's 5- to 10-mA quiescent current rating was imposing limitations. Component manufacturers had already reduced power consumption and operating voltage by producing the standard 555 in CMOS, which is how most of us think of it now, and parts have been developed requiring only 250uA quiescent current and operating down to 2 volts.

As an illustration, the following equations are used to calculate the values of the external components to give the familiar monostable and astable circuits as shown in **figures 1a and 1b.**

Monostable : time t = 1.63RAC

Astable : frequency f = 0.62/(RA + 2RB)C

The graph in **figure 2** represents the ZSCT1555 quiescent current versus supply voltage characteristic. Battery life is optimised by the very low 1.5-volt quiescent power consumption. Only 0.12mW is taken by the timer.

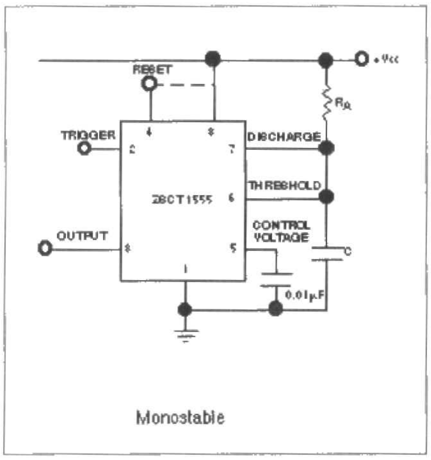


Figure 1a: Monostable

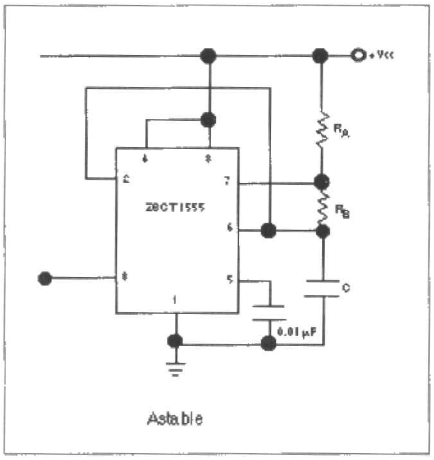


Figure 1b: Astable

A sample application

The following application from Zetex gives an idea the ZSCT1555's capabilites. Until recently most portable circuits have needed 4 to 6 battery cells. The circuit in **figure 3** uses surface mount components to save size and weight for portable equipment, and yet gains improved efficiency and cost reductions. As the supply can operate from a single battery cell, the circuit is ideal for battery applications. The configuration illustrated generates a 5-volt output and allows longer battery life than cmos 555 timer circuits.

The circuit uses a boost topology coupled with pulse width modulation to regulate the output voltage to 5V. The ZSCT1555 generates the required 150kHz signal for the PWM circuit.

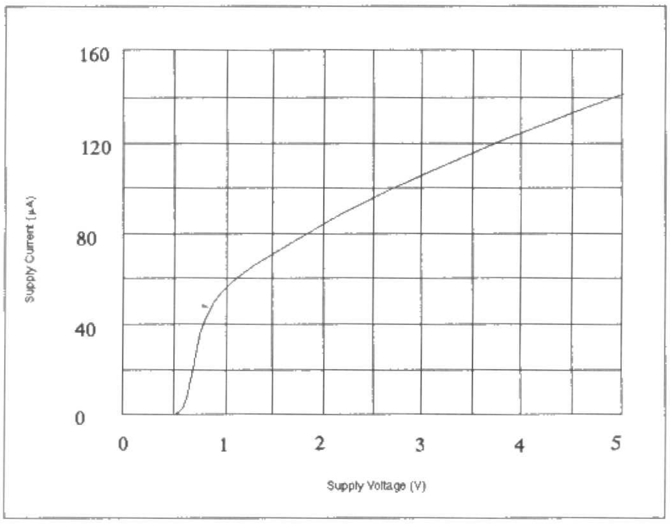


Figure 2: Quiescent current versus supply voltage characteristic in the ZSCT1555

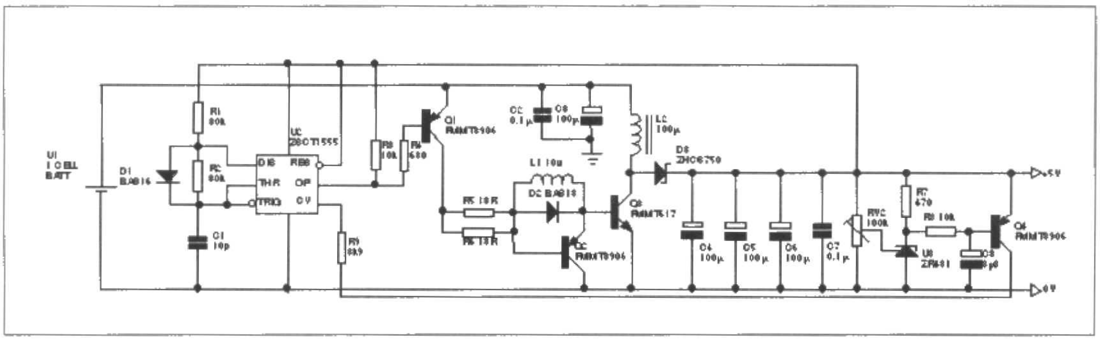


Figure 3: Single cell boost converter circuit

The combination of L1, D2 and Q2 (the Zetex FMMT3904) allows operation up to a very high switching frequency. This circuit uses active base drive to give improved speed and minimum switching losses. The Schottky diode, D3, is used for charge steering. The ZHCS750 gives exceptional DC rating at 750mA. The circuit also features a ZR431 adjustable shunt regulator (U3) in the feedback control loop. The quiescent current of this device is only 35uA.

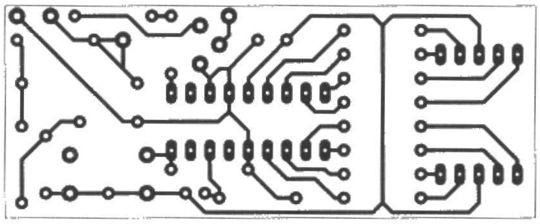
The extremely low saturation voltage, equating to an on-resistance of only 30 milliohms at 300mA, of the FMMT617 switching transistor, Q3, makes the circuit more efficient still.

To help to meet the design objective of bringing the popular chip into the 21st century, Zetex turned to long-term associate Hans Camenzind, of Array Design, California - who was also responsible for the original 555 design with Signetics.

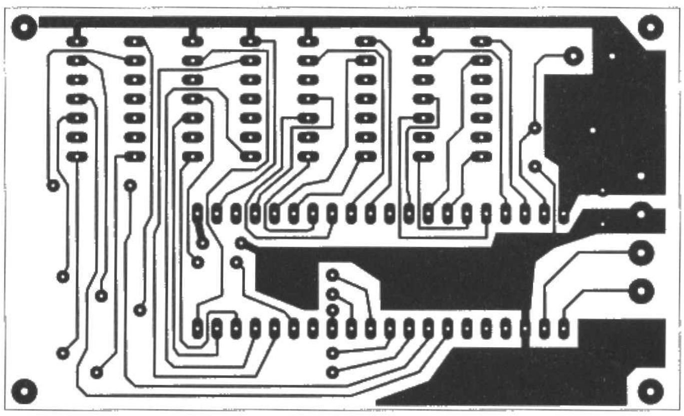
The ZSCT1555 is currently available in DIL or SO formats. Zetex also plans to release the device in the MSOP8 package in the future, offering a footprint about 30 percent smaller than SO8. The new ZSCT1555 is currently being quoted in industrial quantities, but the word from Zetex UK is that it will be featured in the next issue of the Farnell catalogue. For more information see Web www.zetex.com or contact Zetex Plc., Fields New Road, Chadderton, Oldham OL9 8NP Tel 0161 622 4422 Fax 0161 622 4420 email uk.sales@zetex.com

ETI ELECTRONICS TODAY INTERNATIONAL

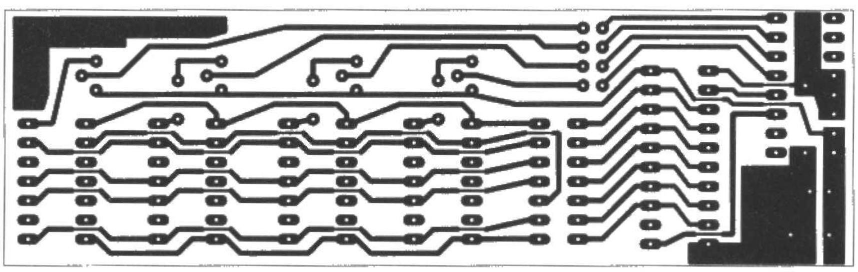
FOILS FOR THIS ISSUE



PIC Electronics Security Switch

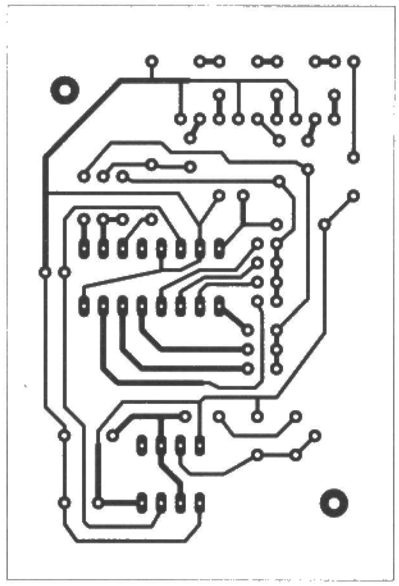


PIC Non-multiplexed LED Display

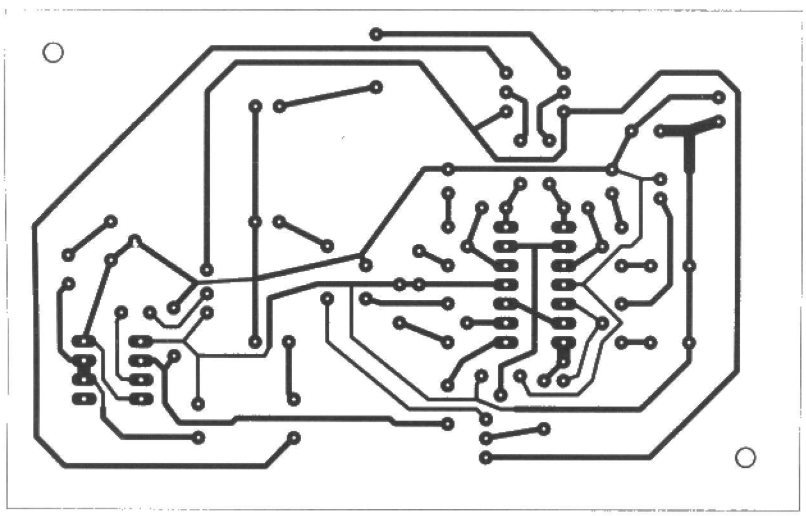


PIC Multiplexed LED Display

FOILS FOR THIS ISSUE



Tiny Traffic Lights



Easy Parker

PRACTICALLY SPEAKING

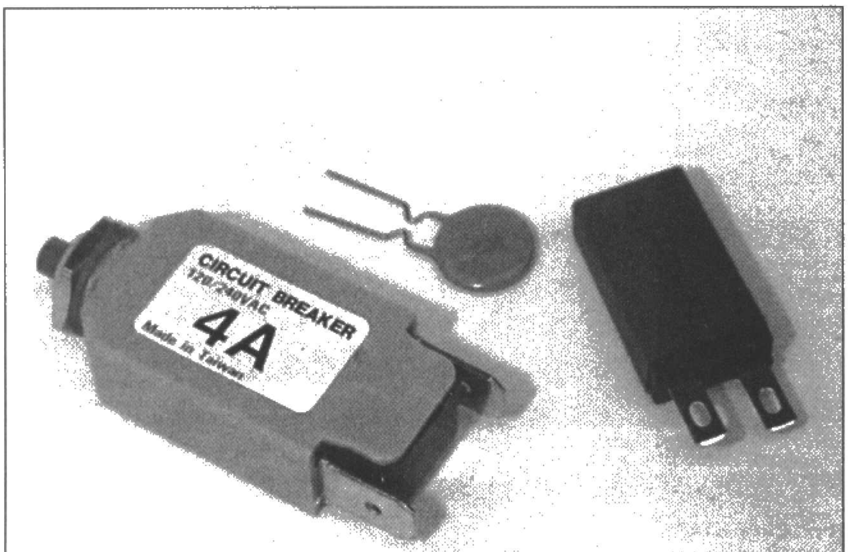
TERRY BALBIRNIE

Over the last two months, we have been looking at the topic of choosing fuses for circuits. I shall conclude this time with some special types of fuse and also have a look at the Residual Current Device (RCD).

Electronic fuses

As well as the traditional "melting wire" type of fuse discussed in previous parts of Practically Speaking, there are some other devices which perform a similar function. One of these is the electronic fuse. This is connected like an ordinary fuse and, like an ordinary fuse, has a certain current rating. At a low temperature, the device has a small resistance and little effect on the current. As the current increases, the fuse becomes warm but the resistance increases only slightly. However, if the current increases above the rated value, the material reaches a critical temperature (about 120 degrees C) and its resistance suddenly increases to a high value. Now, a certain "holding current" flows, and this keeps the fuse hot. The supply is practically disconnected (though not completely so) and it remains like this until the fault is corrected or the supply is switched off. The fuse then cools down and the resistance falls to the "cold" value once again.

An electronic fuse may be soldered into the circuit and forgotten. However, it must not be used to replace a "quick-blow" fuse because it is relatively slow to operate. Also, it remains hot and draws current while in its "tripped" state. Electronic fuses are available in values ranging from about 100mA to 10A and may be used with supplies up to about 60V.



Left: a one-shot circuit breaker. Centre: an electronic fuse. Right: a self-resetting circuit breaker.

Circuit breaker

Circuit breakers perform a function similar to a fuse. There are two types: self re-setting and one-shot. The latter requires a button to be pressed to reset it (see photograph).

Circuit breakers which are designed for low voltage applications are known as a CBEs (circuit breakers for equipment). The kind used for mains supplies and which usually replaces the fuses in a household fusebox is known as a MCB (miniature circuit breaker). Circuit breakers are more bulky than fuses. However, they are useful where the occasional short circuit or overload is expected, such as in bench power supply unit. They can be bought with trip currents ranging from about 0.5A to 15A.

Residual current device

The residual current device (RCD) is often confused with the circuit breaker, but it performs a different function. The RCD is designed to protect the user against a mains electric shock, unlike a fuse which provides protection against excessive current, overheating and fire. The RCD may be combined with a circuit breaker in one package and is then called a RCBO (residual current circuit breaker with over-current protection).

The most usual cause of electric shock is touching a mains Live wire, perhaps through a frayed or broken cable or through a break in the casing of a piece of equipment. Current then flows through the body to earth (the mains neutral is connected to earth). Since the earth conducts electricity, it is especially possible to receive a shock this way in damp conditions where the feet are in effective contact with the ground.

The RCD monitors the current in the live and neutral wires. Normally these will be the same. However, if current flows to earth there will be an imbalance between them (the difference being the amount that flows to earth). This is detected by the RCD. When it reaches a predetermined tripping level, it cuts off the supply. This should occur so quickly that the user does not receive a potentially fatal shock. The relevant British Standard states that the tripping current should not exceed 30mA and the trip speed should not be greater than 200milliseconds. However, the popular household types trip within about 40ms. RCDs can be made to trip with a lower current. However, these are often too sensitive and operate with small earth leakages which naturally occur in pieces of equipment. Modern RCDs interrupt both poles (live and neutral) of the supply and are therefore safer than older types which only cut the live.

The use of an RCD is essential where mains equipment is used in the garden or in any damp situation. It is also essential when testing experimental equipment.

Round the Corner

The Next Generation

For at least two decades, Moore's Law has remained true. Moore's Law states that the number of transistors possible on a single chip of a given size will double approximately every 18 months. This is not intuitively obvious, and it has long been expected to break down because of certain technological problems. So far, news of its demise has been premature.

Back in the mid 1970s, our semiconductors lecturer was already talking of "silicon technology overstretch". The problem anticipated was that, a number of years in the future, the wavelength of light used for photolithography would be the same as the feature size on the chips. This would cause problems on two levels: on the scientific level, where you obviously cannot image something smaller than the wavelength you are using, and on the technological level, increasing the demand for shorter wavelengths.

The technological solution still has drawbacks. If you shorten the wavelength sufficiently, eventually the photon energy becomes so high that no practical mask will block it. Certainly, once you reach the stage of using X-rays, any plausible type of mask will not work.

What has happened instead is that new techniques of imaging features smaller than the available wavelength have been developed. To add to this, a number of other developments have enhanced the capability and density of semiconductor devices, for example the use of electron beams.

One reason why Moore's Law has remained true for so long is that the rate of reduction in feature size need not be a linear match to the rate of transistor increase. If chips were one-dimensional, one would have to halve the size to double the number of transistors along a line.

However, because chips are two-dimensional, all that is necessary is that the square root of the feature size should halve. Roughly speaking, the number of transistors can double if the feature size is reduced by 30 percent.

However, this will still lead eventually to a situation where this is only room for the minimum number of atoms per transistor to permit transistor action to take place. Surely Moore's Law will break down at that stage?

Maybe. Several things may happen to keep it going. First, there are quantum transistors, which use fewer atoms than regular transistors. Then there is the possibility of three-dimensional fabrication. At present, this seems no more plausible than was the ability to image features smaller than a wavelength of visible light did a few years ago. If 3-D fabrication were possible, only the cube root of feature size would need to halve for the number of transistors to double, so a 12.5 percent reduction in feature size would do the trick.

No doubt, like any technological phenomenon, the rapid doubling of transistors per chip will slow down eventually. But what's the betting another technological avenue will have opened? Consider computing: first, mechanical adding machines; then valve computers; then boards full of discrete transistors; then the higher-generation integrated circuits. What next? Digital memory encoding multiple bits per atom? Mechanical organic computers using machinery like that inside a biological cell?

Whatever comes next, I predict that electronics has several more decades of rapid development to run before it even begins to change shape out of recognition. I firmly expect to be able to carry in my pocket or on my wrist something cleverer than I am (and I don't mean a white mouse) during my working life. I also expect it to be electronic, in part or entirely.

Next Month

Volume 27 no. 9 of *Electronics Today International* will be in your newsagents on 14th August 1998 ... Light, sound or capacitance, take your pick: we follow up this month's feature on electronics security with the fascinating world of fingerprint reading ... Some different applications for diodes, by Keith Garwell ... Multiple circuits for music lovers, including a "Jimi Hendrix" sound ... Mark Roberts' sine-wave generator plugs into your PC printer port gives you an on-screen display ... plus software reviews and industry news and all the regulars.

Contents are in preparation but are subject to space and availability.

ETI ELECTRONICS TODAY INTERNATIONAL

Published by
Nexus Special Interests Limited
Nexus House, Azalea Drive,
Swanley, Kent BR8 8HU
Tel: 01322 660070 Fax: 01322 615636

Sorry, we cannot answer queries about projects or other technical question on the phone. Please write to the address above. Our admin assistant can often help with other queries about this issue

Dont Worry! All mail will be forwarded from our previous address.

Our web is http://www.aaelectron.co.uk/eti/
Email address: eti@aaelectron.co.uk.
Please note! This is currently only an editorial web site. Please send enquiries about subscriptions, advertising etc. to Nexus Special Interests' postal address above.

EDITORIAL

Editor
Helen Armstrong
Administration Assistant
Jenny Etheridge
Consultant
Andrew Armstrong

PRODUCTION

Designer
Paul Forster
Technical Illustrator
John Puczynski
Production Executive
Marie Quilter
Printed By
Wiltshire Ltd., Bristol
Origination by
Atelier, St. Austell

SALES

Group Advertisement Manager
Diane Farnham
Midland and Southern Area Sales
Mark Colyer
01322 660070
Northern Area Sales
Denise Barrow
0161 776 4460
Newstrade Sales Manager
David Pagendam

MANAGEMENT

Group Managing Director
Tony DeBell
Divisional Managing Editor
Dawn Frosdick-Hopley
Divisional Sales Manager
Roy Kemp
Circulation Manager
William Pearson
Group Marketing Manager
Aileen O'Connor

SUBSCRIPTIONS

UK:Orders 01858 435344
Enquiries 01858 435322
USA: Wise Owl Worldwide Publications. 4314 West 238th Street, Torrance, CA90505-4509, USA. For VISA/Mastercard orders phone: (310) 375 6258. Fax: (310) 375 0548. Pacific Time: 9am - 9pm weekdays 10am - 6pm weekends. Visa/MC/Discover accepted.

READERS SERVICES
Back issues(last 12 months) £3.20 per issue if available. Binders for ETI: £7.50 each including UK post and packing. Overseas please add £1.50. Cheques to Nexus Special Interest at Nexus House, or phone VISA/Mastercard orders to Readers Services Department 01322 660070

FOR ENTHUSIASTS • BY ENTHUSIASTS
NEXUS

ISSN 0142-7229